# VARIABILITY OF STRIDE FREQUENCY AND PRONATION VELOCITY DURING A 16 DAY RELAY-RUN AROUND GERMANY – A CASE STUDY

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This case study analyzed stride frequency, represented by time of gait cycle (TGC), and maximum pronation velocity (MPV) for one subject running 350 km over 16 consecutive days. Data collection took place during a day-and-night team relay-race around Germany in 2008. TGC and MPV measurements were performed by a gyrometer incorporated in the subject's running shoe and recorded by a portable data logger. For data analysis TGC and MPV velocity were determined in 25 runs for altogether 112,532 steps of the right foot. Means and standard deviations of both parameters for complete runs and for all consecutive five-minute segments within each run were calculated. Results showed an increase of TGC and a decrease of MPV within single runs. Between run comparisons across all 25 runs showed no systematic change in TGC and MPV during the relay-race. Interestingly, during the unfamiliar night-runs TGC and MPV were increased compared to day-runs, potentially caused by altered biorhythm or limited vision at night.

**KEY WORDS:** running, pronation velocity, fatigue, mobile measurements

**INTRODUCTION:** Biomechanical research on distance running primarily focuses on injury prevention aspects, addressing those variables that characterize impact and rearfoot motion. Excessive pronation and pronation velocity are considered risk factors for achillodynia and knee injuries (Brüggemann et al., 2007; Grau & Horstmann, 2007). Thus, rearfoot stability characteristics are deemed an important aspect of injury prevention and rehabilitation.

Study designs addressing running style modification due to prolonged runs and fatigue include intervention studies with measurements right before and after a running intervention (Butler, Hamill & Davis, 2007) but also continuous measurement protocols that allow data collection at different times during the actual run (Brüggemann et al., 1995; Sterzing & Hennig, 1999; Derrick et al., 2002). The latter represent a more realistic running scenario. However, results of these studies are not uniform. Some studies report an increase in pronation and pronation velocity values (Derrick et al., 2002) while others do not observe this behaviour (Sterzing & Hennig, 1999; Butler, Hamill & Davis, 2007).

In addition to biomechanical variables, extreme mileages, and sudden increase of mileage are considered risk factors for running injuries. O'Toole (1992) reported that a relatively high increase in running mileage over a short period of time puts runners at risk for getting injured. Referring to these considerations, Heidenfelder et al. (2009) examined the running style of 11 runners one day before and one day after a 16-day team relay-race around Germany, which required each athlete to run approximately 300 to 350 kilometres. No systematic changes in any of the biomechanical impact or rearfoot motion variables were found for the group of runners or for individual athletes. It was concluded that the fundamental running style of runners is strongly determined and thus not subject to change fundamentally even due to extreme mileage interventions.

All of the referenced studies have in common that they may have induced artefacts not occurring during realistic outdoor running (laboratory, treadmill, instrumentation backpacks). Recently, there have been innovative efforts to implement mobile measuring devices to this research area. A miniature gyrometer attached to the shoe was shown to provide similar pronation velocity information as the established motion analysis and electrogoniometer approaches with a correlation coefficient for pronation velocity determination of 0.72 compared to a Vicon motion analysis system (Brauner, Sterzing & Milani, 2009a). These findings allow the study of pronation velocity in realistic running situations by an instrumented shoe not interfering at all with the runner. The measurement technique was shown to allow

reliable recognition of gait cycle characteristics and determination of maximum pronation velocity within and across runners (Brauner et al., 2009b).
The purpose of this study was to examine time of gait cycle (TGC) and maximum pronation velocity (MPV) and corresponding variability in a one subject case study during a 16 day-and-night team relay-race around Germany in 2008 (www.lauf-kultour.de). Furthermore, as one half of the runs took place during day and the other half during night we looked at TGC and MPV values at full daylight compared to values at night during reduced visibility.

**METHODS:** One injury free male subject (27 yrs, 83 kg, 182 cm) participated in this study measured during a 16 day-and-night team relay-race. He was required to perform two runs per day (4am and 4pm) adding up to a total of 30 runs.

**Figure 1: Subject/ measurement-setup: Instrumented shoe, integrated miniature gyrometer and data logger at a waist belt**

Running times were recorded and distances were determined using a high-sensitivity GPS receiver (*GARMIN, eTrex® H, Garmin International Inc., Olathe, KS, USA*). Mean duration of the runs was 59.65 ± 26.4 min with an average distance of 11.9 ± 4.3 km resulting in a mean running velocity of 3.4 ± 0.3 m $s^{-1}$.
During each of these runs the subject wore an instrumented running shoe (*Saucony Progrid Ride M 28025-3*) with an integrated gyrometer (*Murata ENC-03R, Murata Manufacturing Company, Ltd., Japan*) on his right foot. This instrumentation was developed for mobile pronation velocity measurements and its use showed high correlation to frontal plane kinematics measured with a Vicon 3D motion analysis system (Brauner et al., 2009b).In their laboratory study the authors were also able to demonstrate that the gyrometer could be used without any calibration process for pronation velocity measurements. Data was recorded with a data logger at 1000 Hz (*eLAS.net MultiLOG2, MSR-Electronics, Switzerland*). A digital high pass filter at 0.1 Hz (1st order Butterworth) eliminated the sensor inherent drift.
Data of five runs of the first three days had to be eliminated due to a broken sensor, leaving the data of altogether 25 consecutive runs for gait cycle detection and MPV determination according to the previously developed algorithm (Brauner et al., 2009b). A total of 112,532 steps of the right foot (4,501 ± 1,465 per run) were identified, and each corresponding MPV was determined and used for further analysis. Furthermore, TGC was determined and used to interpret dependent stride frequency. Data analysis was divided in between-run and within-run analyses.
*Within-runs analysis*
For Within-runs analysis only the first 50 minutes of each of the 25 runs were analysed. These 50 minutes were divided into ten five-minute intervals. For each five-minute interval, mean and standard deviation of TGC and MPV were calculated. Furthermore, corresponding intervals were averaged over all 25 runs to investigate the effect of fatigue on TGC and MPV within runs (e.g. all 25 first five-minute intervals were averaged to represent the behaviour of the parameter in the first five minutes of a run, then all 25 second five-minute intervals and so on). Consequently, standard deviations were also calculated to represent variability for each calculated mean.
*Between-runs analysis*
For each of the 25 analysed runs means and standard deviations of TGC and MPV were calculated for all steps. This allowed analyzing TGC and MPV variability of single runs and comparing runs within the same day as well as between days.
For statistical analyses only descriptive methods were applied because this case study data shows a descriptive nature. The results can therefore not be used for generalization but they can provide a first impression into pronation behaviour of a single runner during prolonged field testing.

**RESULTS AND DISCUSSION:** Within-run analyses unveil a continuous increase of TGC and reduction of MPV over the time of each run (Figure 2). The reduction of MPV during the course of a run supports the findings of Sterzing & Hennig (1999) and Butler, Hamill & Davis (2007) but is in direct contrast to Derrick et al. (2002), who state increased pronation velocity during prolonged runs.

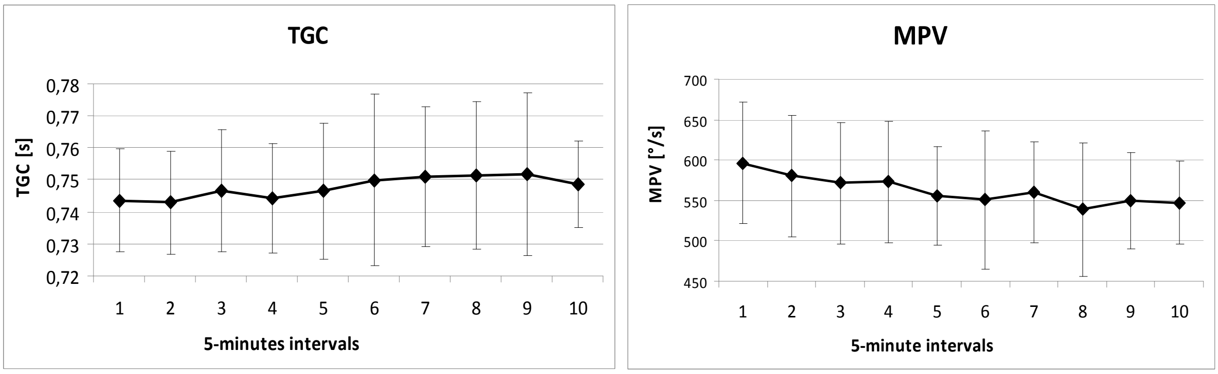


**Figure 2: Within-run analysis: Averaged values over 25 runs for each five-minute interval**

A fatigue effect over the complete period of the 25 runs was not observed, since TGC and MPV showed no systematic trend over all runs (Figure 3). Also, standard deviations of both variables were lower in single runs ($SD_{TGC}$=0.046, $SD_{MPV}$=118.1) than between runs ($SD_{TGC}$=0.016, $SD_{MPV}$=58.9), consolidating the observed effects. Astonishingly, variability of TGC was highly increased towards the end of the running event, as standard deviation of the last seven runs showed 2.9 times higher values compared to the first 18 runs.

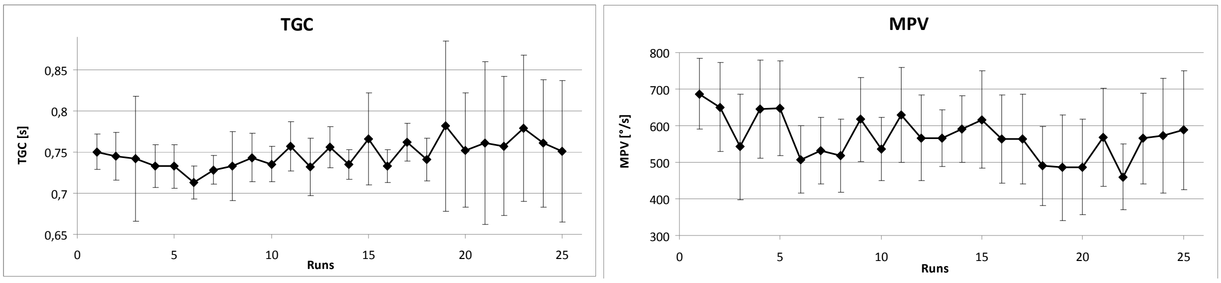


**Figure 3: Between-run analysis: Mean values for each run**

Interestingly, systematic differences occurred between day-runs and night-runs for both variables. Ten of eleven day-night comparisons (runs within 24 hours) unveiled higher MPV averages during night-runs in contrast to day-runs that took place within 24 hours (Figure 4).

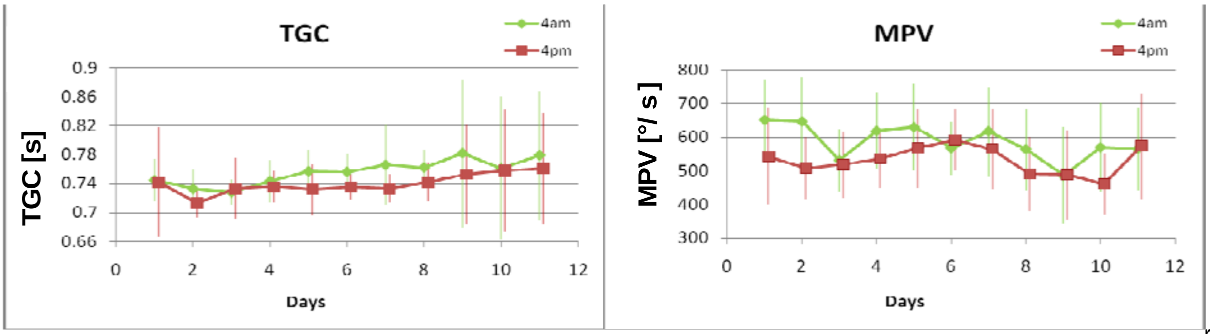


**Figure 4: Day-night analysis: Mean values of runs at 4am and 4pm**

subject reduced his stride frequency while increasing maximum pronation velocity during night runs. Night runs took place at unfamiliar biorhythm, limited vision and also during lower temperature compared to day runs, which are potential explanations for the observed effects.

**CONCLUSION:** Analysis of time of gait cycle and maximum pronation velocity allow deeper insight in athletes running performance characteristics. The methods used in our study allowed to observe these parameters during prolonged outdoor running. The presented decrease of maximum pronation velocity values within single runs for our subject contradicts the findings in the literature. However, this one subject observation needs to be interpreted with highest caution as this case study has no power to state general group effects of prolonged running. It rather marks the basis of a future set of studies aiming to solve the questions that arose during this study.

In future studies, with more subjects, the effects of prolonged running on time of gait cycle and maximum pronation velocity and their corresponding variability needs to be investigated. The proposed reasons (unfamiliar biorhythm, reduced vision, and lower temperature) for day and night run differences of the investigated variables need to be verified. This calls for systematically arranged follow-up studies approaching these issues.
The further enhancement of mobile measurement technology should provide better suited tools in order to deal with aspects aiming to link running characteristics to running injuries, a research area that is highly interesting but has not been able to come up with clear answers so far.

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