Running Asymmetries during a 5-Km Time Trial and their Changes over Time

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Abstract: Gait Asymmetry during Running Was Proven to Be Inefficient, Uneconomical and a Possible Risk Factor for injury. Research has either been conducted in laboratory settings or only discontinuous data were collected. Hence, the present study evaluated gait asymmetries in elite runners by quantifying the differences between ground contact times (GCT) of the right and left foot and their continuous changes over the course of a 5-km time trial. Data of 25 female and male runners of the Swiss orienteering national team were obtained during a 5-km competition on a 400-m outdoor track. By means of the inertial sensor PARTwear, GCT of every step were assessed, divided into GCT of the left and right foot and averaged over 200-m sections. The results revealed an overall asymmetry of 2.6%, significant ($p < 0.01$) longer GCT during left than right foot contacts and no changes in asymmetry over the course. This is the first study presenting data on asymmetries in elite athletes during a competitive time trial. In conclusion, low and consistent GCT asymmetries were observed. The examined athletes had a balanced running style and showed no adverse asymmetry with emerging fatigue, which in turn could affect acute performance and increase injury risk.

1 INTRODUCTION

There is an impressive number of studies conducted on mechanics in running. Parameters of interest are among others step length, step frequency, breaking time, aerial time and ground contact time (Girard et al., 2013; Murphy et al., 2003; Nummela et al., 2013). Knowledge on these parameters is relevant for athletes, coaches and researchers. The athlete and the coach need objective information to improve running technique and performance, whereas researchers need those running parameters to gain new knowledge about key performance indicators and injury risk factors. One possible risk factor identified in the literature is lower limb asymmetry, which has been proven to impact the incidence of injuries and possibly affect athletic performance (Croisier et al., 2002). It is obvious that a certain asymmetry is normal, as the running style is optimized over the years of training. Yet, the threshold at which a deficit becomes problematic is still to be defined. In terms of limb asymmetry, a threshold of 15% has been stated for return to sport after rehabilitation programs (Myer et al., 2006). However, it is unclear how threshold values were derived and findings from cross-sectional studies have been inconclusive. Moreover, there is a lack of evidence when data were obtained at maximal speeds during middle- to long- distance runs. This may be important, as with increasing intensity step variability was shown to increase (Belli et al., 1995). Additionally, no previous research investigated the changes over time concerning running asymmetry. Such information might provide an insight into the onset and progression of the athlete's fatigue and potential adaptations in running style. Asymmetry might not be evident during the start phase of a race, but may arise with the development of muscular fatigue.

It is difficult to determine most relevant parameters to assess asymmetry. Running depends on a variety of parameters but at the end it comes all down to ground contact time (GCT), as it is the only moment during running to generate propulsive force, hence, to move on. The ability to produce and transmit high amounts of muscular force to the ground over a short period of time is a major determinant of performance in running (Weyand et al., 2000). It was reported that shorter GCT is faster and more energy efficient than longer GCT (Nummela et al., 2007). The less economical runners

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have lower vertical leg stiffness, which leads to enhanced braking time, and therefore, longer GCT. Hence, measuring GCT may be of potential benefit to investigate the presence of asymmetry and other alterations as they occur during running. Previous research showed 3.5% running asymmetries regarding GCT in Australian Rules football players while running on treadmill at their individual 80% VO2max (Brughelli et al., 2010). Similar, Kong and de Heer (2008) reported an average 3.6% asymmetry between GCT of both feet in male Kenyan distance runners. Six gait cycles each, obtained on treadmill at five submaximal speeds, were analyzed in that study.

So far, the focus in the literature on mechanics in running lies on constant velocity runs, mainly on treadmill, or sprint protocols in the laboratory (Brughelli et al., 2010; Kong and de Heer, 2008; Lee et al., 2010; Rumpf et al., 2014). However, technology applied is somewhat limited and restricted to a specific place, which in turn might affect running patterns. To seriously work on a specific parameter and to investigate its variability over different phases of a distance, the measurement system should be applicable in field conditions and during entire trials. By means of portable, light-weighted, and valid inertial sensors the analysis of stride parameters, such as GCT, is possible in the field over a whole time trial, anywhere and anytime. So far, no studies have evaluated the occurrence and change of asymmetries in GCT during maximal running performance under field conditions. Therefore, the aim of the present study was to examine the asymmetries between GCT of the right and left foot in elite runners and their continuous changes over the course of a 5-km time trial on an outdoor synthetic track.

2 METHODS

2.1 Subjects

A total of 10 female and 15 male (24.5 ±3.4 years, 174.8 ±9.0 cm, 63.0 ±8.1 kg) orienteers, competing at international level, were recruited to participate in the study. The local ethics committee approved the study and all participants provided written informed consent before testing. A medical questionnaire was administered to exclude athletes with any known lower limb injury in the past 6 months.

2.2 Procedure

The measurements took place during a competitive 5-km running time trial of the Swiss orienteering national team. The time trial was one part of selection criterion for the participation in the upcoming world championships. After an individual warm-up session the runs were carried out on a 400-m outdoor synthetic track. The male and female runners started as a group, respectively, whereby the gender groups were again split in half to avoid too many runners on track at the same time. The athletes were free to choose their own pace in order to realize the shortest time possible over the 5-km. Additionally to their own sport watch, split times were provided every 200-m including verbal encouragement. The time trials were performed in sunny weather with no wind and air temperature constant at 24 °C.

2.3 Data Collection

Before the start of the testing, each subject received two PARTwear sensors (HuCE-microLab, University of Applied Sciences, Biel, Switzerland). The sensors' validity and reliability in terms of GCT was recently demonstrated (Ammann et al., under revision). Two sensors were attached, by means of customized elastics, to the shoe laces of the left and right foot. The PARTwear sensor (size: 3.8 x 3.7 x 0.8 cm; weight: 13 g) consists of a 9-axis MotionTracking™ device MPU-9150 (InvenSense, Inc., San Jose, CA, USA) that combines a 3-axial accelerometer, a 3-axis gyroscope, and a 3-axis magnetometer. Accelerometer data was recorded with a full-scale range of ±16 g and a sampling rate of 1,000 Hz. Sensor operation and data transmission was established via Bluetooth and data processing took place by the proprietary software. In order to assess split times per 200-m for every athlete, two video cameras (Handycam HDR-CX700VE, Sony Corporation, Tokio, Japan) were placed on the track, one on the 200-m line and one on the finishing line.

2.4 Statistical Analysis

Running velocity and GCT were averaged for each of the 25 segments of 200-m. Relative asymmetry in GCT between both feet was computed as in equation 1.

$$\sqrt{((\text{right GCT} - \text{left GCT}) \,/\, \text{left GCT} * 100)^2} = \% \quad (1)$$

Statistical analyses were performed by using SPSS Statistics 22 and the level of significance was set at $p \leq 0.05$. Data were expressed as overall means ±*SD* and illustrated by means of boxplots. Asymmetry between GCT of the left and right foot was calculated by a paired samples *t*-test. The effect of running distance on asymmetry was evaluated by a repeated measures ANOVA.

3 RESULTS

Mean 5-km performance time for both gender was 17 min 06 s ±1 min 39 s (ranging from 14 min 43 s to 20 min 21 s), resulting in an average speed of 4.92 ±0.48 $m \cdot s^{-1}$ (Table 1). Men were running significantly ($p < 0.01$) faster than women and had shorter GCT. Overall, the GCT of the left foot was significantly ($p < 0.01$) longer compared to the GCT of the right foot (194.4 vs 193.0 ms). The observed asymmetries between GCT of the left and right foot were 2.57 ±2.14% without gender differences. The applied repeated measures ANOVA with a Greenhouse-Geisser correction revealed no significant changes over the 25 segments of 200-m ($F_{4.2,\ 100.7} = 1.645$, $p = .166$). Figure 1 illustrates the changes in asymmetries over time.

Table 1: Subjects' performance presented as means ±*SD*.

	Overall	Women	Men
5-km time	17:06	18:54	15:55**
[min:ss]	±01:39	±00:56	±00:35
Speed	4.92	4.42	5.24**
[$m \cdot s^{-1}$]	±0.48	±0.26	±0.26
GCT	193.7	199.3	190.0**
[ms]	±14.3	±13.9	±13.3
Asymmetry	2.57	2.47	2.65
[%]	±2.14	±1.79	±2.34

** $p < 0.01$ between gender.

4 DISCUSSION

The present study sought to examine gait asymmetries during running and their changes over a 5-km time trial. Asymmetry was quantified by the difference between the GCT of the left and right foot. Overall, asymmetry in all elite orienteers was 2.6%. This was noticeable lesser when compared to Brughelli et al. (2010) and Kong and de Heer (2008) who reported 3.5% and 3.6% asymmetry in GCT, respectively. However, it is difficult to make direct comparisons between studies as the applied methodologies differed. The cited studies obtained data of male subjects on treadmill at submaximal speeds. Moreover, subjects were Australian Rules football players demonstrating a different running style compared to athletic running specialists (Brughelli et al., 2010). Or else, data were measured during six step cycles only, which was reported to be very little, and therefore, less conclusive (Belli et al., 1995; Kong and de Heer, 2008). The current 5-km time trial was executed under field conditions that automatically lead to greater variability in pacing. This in turn could impact asymmetry even more. However, it appeared that the present female and male elite athletes had smaller asymmetries although running at maximal velocity over approximately 17 min.

Interestingly, the athletes in the present study kept gait asymmetries constant over the entire course of 5-km because no 200-m segment could be detected as being particularly different to the others (Figure 1). Related literature is lacking, and therefore, in previous research on sprint running it was recommended to obtain data of longer distances than 30-m because asymmetries might differ during different phases or at steady state running (Rumpf et al., 2014). However, in the current study this assumption could not be confirmed as no progression in asymmetries over time was observed. Hence, our elite athletes were able to consistently deal with the emerging fatigue and they did not show potential physical limitations in an uneconomical imbalanced behavior, which in turn could have increased injury risk.

Throughout the run, the GCT were significantly longer during the left than the right foot contacts. One could assume that the left leg is on the inside lane of the 400-m synthetic track and that running the curve would have an impact on GCT asymmetry. This observation was in line with the study of Kong and de Heer (2008) who also reported longer GCT with the left foot. However, as their study was conducted on treadmill the impact of the curve and inside line of the track is questionable.

Noteworthy, individual asymmetry is masked when data is averaged for a whole sample, like in the present study. Therefore, in high performance settings data should remain individualized when assessing athlete's strengths and weaknesses for diagnostic and prognostic purposes. Furthermore, obtaining long-term measurements could be useful, as classifying one's deficits after an injury is difficult when individual baseline data are lacking. Having long-term data at hand would be useful for athletes, coaches, and medical staff to e.g., monitor return to sport after a rehabilitation program. Also, the present results might be important to bear in mind for young talents that they should aim for symmetric running patterns throughout time trials. Recently, due to maturation substantial greater asymmetries in youths regarding horizontal and vertical forces were reported (Rumpf et al., 2014). Hence, it may be meaningful to youth coaches to compare young talents to elite

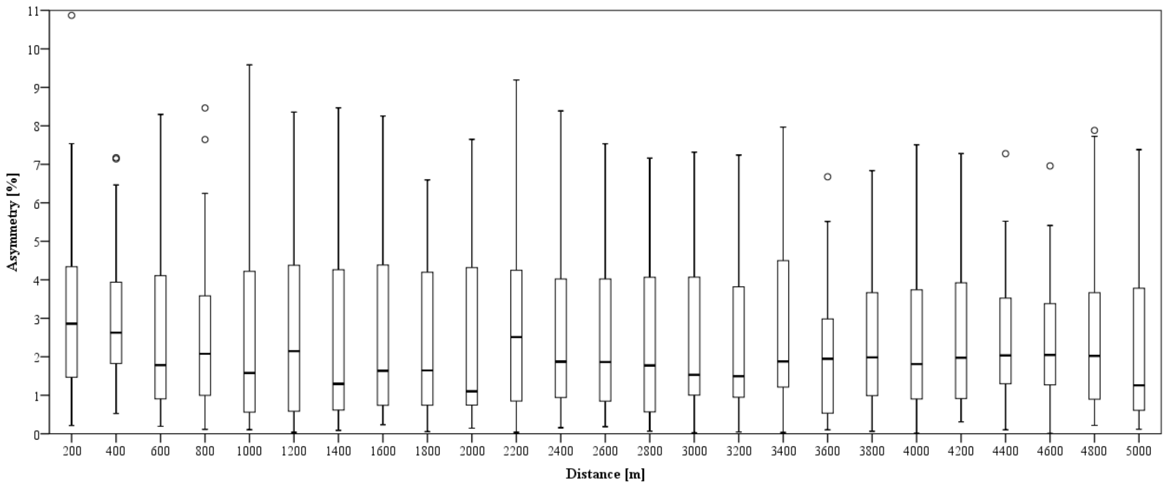

Figure 1: Relative differences in ground contact times between both feet at each 200-m segment during the 5-km time trial. No significant asymmetry changes over time.

athletes in same settings.

The PARTwear sensor seems to be a device with high practical application to regularly monitor and evaluate gait asymmetries in running during entire training sessions and competitions. The sensor is light-weighted and does not hamper the athlete when running. Additionally, data can be evaluated in real time even for a group of athletes.

5 CONCLUSIONS

The present study showed very low and consistent GCT asymmetries in elite orienteers over a 5-km running time trail. The athletess appeared to have the ability to compensate emerging fatigue in an efficient, at least not adverse, manner, as no alteration in asymmetry occurred over time. By means of the used technology subsequent data will be obtained to further investigate gait asymmetries in e.g., young talents, different distances and speeds or inside versus outside lane of the track.

REFERENCES

Ammann, R., Taube, W., & Wyss, T. (under revision) Accuracy of PARTwear inertial sensor and Optojump optical measurement system for measuring ground contact time during running. *J Strength Cond Res.*

Belli, A., Lacour, J.R., Komi, P.V., Candau, R., & Denis, C. (1995) Mechanical step variability during treadmill running. *Eur J Appl Physiol* 70: 510-517.

Brughelli, M., Cronin, J., Mendiguchia, J., Kinsella, D., & Nosaka, K. (2010) Contralateral leg deficits in kinetic and kinematic variables during running in Australian Rules football players with previous hamstring injuries. *J Strength Cond Res* 24: 2539-2544.

Croisier, J.L., Forthomme, B., Namurois, M.H., Vanderthommen, M., & Crielaard, J.M. (2002) Hamstring muscle strain recurrence and strength performance disorders. *Am J Sports Med 30*: 199-203.

Girard, O., Millet, G.P., Slawinski, J., Racinais, S., & Micallef, J.P. (2013) Changes in running mechanics and spring-mass behaviour during a 5-km time trial. *Int J Sports Med* 34: 832-840.

Kong, P.W., & de Heer, H. (2008) Antropometric, gait and strength characteristics of Kenyan distance runners. *J Sports Sci Med* 7: 499-504.

Lee, J.B., Sutter, K.J., Askew, C.D., & Burkett, B.J. (2010) Identifying symmetry in running gait using a single inertial sensor. *J Sci Med Sport* 13: 559-563.

Myer, G.D., Paterno, M.V., Ford, K.R., Quatman, C.E., & Hewett, T.E. (2006) Rehabilitation after anterior cruciate ligament reconstruction: Criteria-based progression through the return-to-sport phase. *J Orthop Sports Phys Ther* 36: 385-402.

Murphy, J.A., Robert, G.L., & Coutts, A.J. (2003) Kinematic determinants of early acceleration in field sport athletes. *J Sports Sci Med* 2: 144-150.

Nummela, A., Keranen, T., & Mikkelsson, L.O. (2007) Factors related to top running speed and economy. *Int J Sports Med* 28: 655-661.

Rumpf, M.C., Cronin, J.B., Mohamad, I.N., Mohamad, S., Oliver, J.O., & Hughes, M.G. (2014) Kinetic asymmetries during running in male youth. *Phys Ther Sport* 15: 53-57.

Weyand, P.G., Sternlight, D.B., Bellizzi, M.J., & Wright, S. (2000) Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *J Appl Physiol* 89: 1991-1999.