GAIT COORDINATION VARIABILITY BETWEEN TRAINED RUNNERS AND NON-RUNNERS

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The objective of this study was to examine the differences in coordination variability in gait running between trained runners and non-runners. Kinematic data were collected from 20 participants divided into two groups (runners and non-runners) during treadmill running. Coordination variability was evaluated by calculating continuous relative phase (CRP) for four coupling pairs. The CRP variability averaged over the entire stance phase was equal between both groups of runners in the coupling joint analysed ($t < 1.358$, $P > 0.192$). The results suggest that the skill level did not influence on the CRP variability in running gait.

KEY WORDS: kinematics, continuous relative phase, skill level

INTRODUCTION: Running is a fundamental skill that is acquired during childhood and can be improved with practise. Sustained practise can alter running biomechanics resulting in enhanced running economy and decreased risk of injury (Hreljac & Ferber, 2006). There are various perspectives in the literature on the assessment of running biomechanics, including the analysis of intersegmental coordination (Hamill, Van Emmerik, Heiderscheit, & Li, 1999). It is proposed that a lack of within-limb coordination could increase injury risk or reduce movement efficiency (DeLeo, Dierks, Ferber, & Davis, 2004; Hamill et al., 1999). Since running skill requires multi-segmental movements with multiple degrees of freedom, some coordination variability between strides can be expected. Interpretation of coordination variability between strides can be challenging but generally, a high level of variability could be indicative of a flexible movement control strategy which would enable the runner to have greater adaptability to environmental variations (Hamill et al., 1999). The variability of movement and coordination may be determined by factors such as the skill level of participants in the task. However, the relationship between variability and skill level is complex because this depends on the type of movement analysed (Preatoni et al., 2013). Thus, it cannot be assumed that increased movement variability is attributed to higher levels of ability for any task. Few studies to date have examined the variability of running gait and coordination in relation to skill level. Therefore, the objective of this study was to examine the differences in coordination variability in running gait between trained runners and non-runners. Since the continuous relative phase (CRP) analysis can provide effective analysis of continuous joint coupling between two segments and coordinative variability in running gait (Hamill, Haddad, & McDermott, 2000), this study used CRP to assess coordination variability differences between trained and non-runners.

METHODS: The participants (N = 20) were divided into two groups consisting of: (1) non-runners, who had not undergone distance running training nor practiced recreational running more than two days a week and (2) trained runners, who had undergone running distance training at least five days per week. The non-runners group consisted of 12 females aged 23 ± 3.6 years (mean ± SD), with a mass of 55 ± 5.3 kg and a height of 1.63 ± 0.05 m. The runners group consisted of 8 females aged 22 ± 2.2 years, with a mass of 52 ± 4.5 kg and a height of 1.60 ± 0.06 m. No participants had any past history of nervous system or muscular dysfunction. The study obtained ethical approval from the University's research ethics committee. All participants signed informed consent forms before participating in the study.

A 5-camera VICON motion capture system (Bonita-3, Vicon Motion Systems, Oxford, UK), and 9-mm retro-reflective markers, were used to collect 3-dimensional (3D) kinematic data at

120 Hz during treadmill running. Markers were placed in the same manner described by (Pohl, Lloyd, & Ferber, 2010). In brief, 14 anatomical markers were attached bilaterally to the following landmarks: the greater trochanters, medial and lateral knee joint lines, medial and lateral malleoli, 1st metatarsal heads, and 5th metatarsal heads. Technical marker clusters, glued to a rigid plastic shell, were placed on the pelvis (three markers), and bilateral thigh and shank (four markers each) with self-adhering straps. Three markers were taped to the heel counter of each of the test shoes. These twenty-five markers represented seven rigid segments. Two markers individually placed on the anterior aspect of each shoe were used for used for detecting toe-off events.

Following placement of all the anatomical and segment markers, the subject was asked to stand for a static trial and standing position was controlled using a graphic template placed on the treadmill with their feet positioned 0.3 m apart and pointing straight ahead. Once the feet were placed in the standardized position, the subject was asked to cross their arms over their chest and stand still while one-second of marker location data were recorded to identify joint centre locations and to calculate the segment coordinate systems. Upon completion of the static trial, the 14 markers on the anatomical landmarks were removed. All participants were permitted as much time as they required to familiarize themselves with treadmill running. Running kinematic data were collected while participants ran at a self-selected comfortable speed on a treadmill wearing standard shoes (Nike, Air Pegasus) for 30 seconds during which approximately 30-45 consecutive strides were collected for processing and analysis. After marker trajectories were filtered with a 10 Hz low-pass 2nd order recursive Butterworth filter, 3D rigid body kinematics were calculated using 3D GAIT software (Gait Analysis Systems Inc., Calgary, Alberta, Canada), then segmented and normalized into 100 data points for the stance phase based on a single value decomposition approach outlined by Söderkvist and Wedin (1993) and the joint coordinate system suggested by Cole, Nigg, Ronsky and Yeadon (1993).

CRP variability was calculated using a custom MATLAB routine (The Mathworks, Natick, MA). The angular displacement and angular velocity data sets of each stance phase were interpolated to 101 points. Phase-plane plots were created with angular displacement in the x-axis and angular velocity in the y-axis for each joint movement. The phase-plane plots were normalised to a range of -1 to +1 for the angular displacement and angular velocity was normalised to absolute maximum value (Hamill et al., 1999; Hein et al., 2012; Miller, Meardon, Derrick, & Gillette, 2008). For each phase-plane plot, the phase angle was constructed using the following equation:

$$\emptyset(t) = tan^{-1}\frac{\omega(t)}{\theta(t)}$$

Where: Φ is phase angle, ω is normalised angular velocity, and θ is the normalised angular displacement at time t.

The phase angle was presented in the range 0º and 180º to avoid discontinuities which can appear at the transition from quadrant 2 (180º) to quadrant 3 (-180º), (Hamill et al., 1999; Hein et al., 2012). The CRP between two joints was calculated as the difference between the phase angles. For each coupling, the distal segment was subtracted from the proximal. CRPs were calculated from the phase angles for hip flexion/extension ($HIP_{flex/ex}$) and knee flexion/extension ($KNEE_{flex/ex}$), hip abduction/adduction ($HIP_{abd/ad}$) and knee flexion/extension ($KNEE_{flex/ex}$), knee flexion/extension and ankle flexion/extension, knee flexion/extension subtalar inversion/eversion.

Continuous methods were used to calculate the coordination variability and this was based on the CRP of ten stance phases. CRP variability was calculated as the standard deviation on a point-by-point basis over the complete cycle. From the CRP data, an ensemble average curve as well as the mean and standard deviation of each data point on average curve were calculated. The average of the standard deviations (SD_{avg}) for all strides composing the ensemble average curve were calculated using the following equations (James, 2004):

$$SD_{avg} = \sqrt{\left(\frac{\sum_{i=1}^{k} SD_i^2}{k}\right)}$$

For the equations, SD_{avg} is the average of individual point-by-point standard deviation values, i indicates the specific value for the i^{th} sample, SD_i is the standard deviation value for the i^{th} sample, and k is the number of samples.

All statistical analysis was conducted using PASW (SPSS, Inc., Chicago, IL). A Shapiro-Wilk test was executed to verify the normality of data. An independent samples Student t-test was performed to determine differences between runners and non-runners. Significance level was set at $P < .05$.

RESULTS: The mean and confidence intervals for each coordination variability parameter and for each group are presented in Figure 1. The results showed no significant differences in CRP variability between the non-runners and runners ($t < 1.358$, $P > 0.192$). The CRP variability values across the four couplings analysed ranged from 5.0º to 18.4º. Outcome coordination variability increased as more distal segments were involved in its calculation. The hip flexion-extension coupling pair showed the lowest values of CRP variability ($HIP_{flex/ex}$-$KNEE_{flex/ex}$: non-runners: 5.5, runners: 5.0) and the ankle eversion-inversion coupling pair showed the highest values ($KNEE_{flex/ex}$-$ANKLE_{ev/in}$: non-runners: 18.4, runners: 12.0).

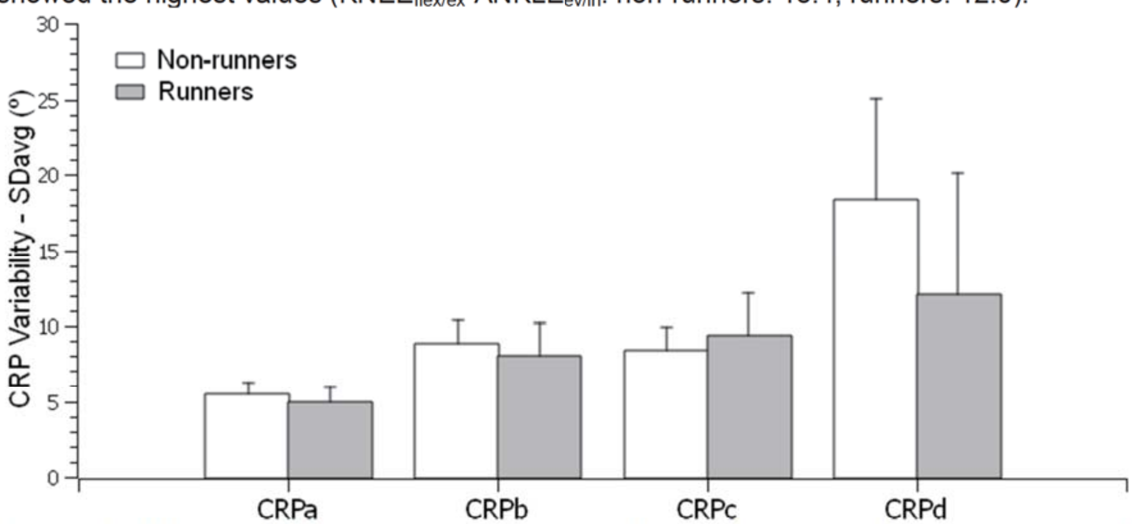

Figure 1: CRP variability for non-runners (white) and runners (grey) groups. 95% confidence intervals and effect sizes values are also presented. CRPa: $HIP_{flex/ex}$-$KNEE_{flex/ex}$, CRPb: $HIPa_{abd/ad}$-$KNEE_{flex/ex}$, CRPc: $KNEE_{flex/ex}$-$ANKLE_{flex/ex}$, CRPd: $KNEE_{flex/ex}$-$ANKLE_{ev/in}$.

DISCUSSION: The main finding in this study was that CRP variability averaged over the entire stance phase was similar between runners and non-runners. This result suggests that the variability of joint coupling during the stance phase does not depend on previous running experience. These results were in general agreement with Cazzola, Pavei and Preatoni (2016) who also reported no differences in coordination variability over the entire gait cycle between race walkers of different skill levels. However, these authors did report between-group differences when the variability was analysed for different functional phases (cushioning, propulsion or flight phases) of walking gait. Thus, future research could analyse running gait during different phase intervals for a better understanding of the role of skill level on the coordination variability (Hein et al., 2012).

The CRP variability values obtained in this study were lower than those reported in the literature (Hein et al., 2012; Miller et al., 2008). This finding could be due to the use of a treadmill to carry out the test. A treadmill imposes a constant speed which can reduce the possible perturbations and/or environment changes which might require lees flexibility in movement execution (Cazzola et al., in press).

This study also showed that coordination variability increased when the coupling calculations included ankle joint eversion-inversion motion. This result suggests that both runners and non-runners used the frontal plane ankle motion to compensate for environmental variations to a greater degree as compared to the hip or knee joints. As well, this result suggests that increased CRP variability may indicate different roles each joints plays to cope with external influences. Further research on this topic is needed.

CONCLUSIONS: This study did not demonstrate any significant differences in CRP variability between runners and non-runners. Therefore, the variability of joint coupling during the stance phase of running gait does not depend on previous running experience.

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