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The effect of external perturbations on variability in joint coupling and single joint variability

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ABSTRACT

This paper explores the effect of goal-oriented external perturbations created by elastic tubes attached to the hip and ankles on lower limb joint variability and hip–knee and knee–ankle coordination variability during running. Kinematics of ten healthy male runners were analysed prior to and following a 7-week tube running intervention while running with and one without this constraint. The training intervention was based on variable training aspects to increase within-movement variability and adaptability of the running pattern. To analyse the effects of the tubes on the running pattern, the phase plot vector length deviation (i.e., the standard deviation of the phase plot vector length) for the within-joint variability and the continuous relative phase variability for the joint coupling variability were calculated. Results revealed acute increases of variability in both parameters. However, after the intervention, variability of the tube running situation returned to normal for all couplings and joints except the knee. No transfer effects to normal running were observed. This suggests very rapid adaptations to such perturbations. In the long-term, it may ask for more or different variations.

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1. Introduction

Running has always been a very popular recreational activity. However, improved fitness and growing ambition lead to an increased amount and intensity of training that is often associated with overuse injuries in the hip, knee or ankle (Hamill, van Emmerik, Heiderscheit, & Li, 1999; Heiderscheit, Hamill, & van Emmerik, 2002; Hein et al., 2012; Stergiou, Jensen, Bates, Scholten, & Tzetzis, 2001). Due to pain-related movement, joint coordination variability has been shown to decrease as a kind of protective mechanism (Van Emmerik & Van Wegen, 2000). The loss of variability, however, results in reduced adaptability or flexibility, which are necessary for optimal functioning of healthy systems (Heiderscheit et al., 2002).

As the mastering and organization of the many degrees of freedom allows the adoption of functional movement patterns (Bernstein, 1967), analysing changes due to continuous training in healthy individuals may reveal possible changes in joint coordination variability and help prevent injuries. Hence, a large number of running studies (e.g., Dierks & Davis, 2007; Gittoes & Wilson, 2010; Hamill et al., 1999; Heiderscheit et al., 2002; Hein et al., 2012) investigated either two populations (i.e., one healthy and one pathological) or report only single measurements done with respect to lower limb joint kinematics and coordination variability. However, limited research is available focusing on the application of stimuli intended to increase variability to regain or maintain a healthy amount of coordination or coupling variability.

Since it is largely accepted that variability is a functional entity that helps establish optimal states of coordination (Hamill, Palmer, & Van Emmerik, 2012; Wheat & Glazier, 2006), investigations that apply perturbations to the movement pattern may help to understand whether inducing external goal-directed perturbations enables an increase of functional variability within the movement pattern (Haudum, Birklbauer, Kröll, & Müller, 2011, 2012). That is, through the application of additional variability, the movement pattern may again become more flexible and, therefore, more adaptable to external perturbations (Haudum et al., 2011, 2012; Schöllhorn, Hegen, & Davids, 2012; Schöllhorn, Mayer-Kress, Newell, & Michelbrink, 2009). This may further help to move more economically due to a transition to a new or at least slightly altered behavioral pattern (Haudum, Birklbauer, & Müller, 2011b). In running, where many degrees of freedom are orchestrated to a stable, coordinated and skillful movement, this approach may include the effect of running under changing conditions or responses to intervention programs in a healthy runners' population (Stergiou, Jensen et al., 2001).

An example for changing conditions or constraints can be obstacles (Stergiou, Jensen et al., 2001), type of shoes (Stöggl, Haudum, Birklbauer, Murrer, & Müller, 2010) or the application of elastic tubes (Haudum, Birklbauer, & Müller, 2012b; Haudum et al., 2011; Haudum et al., 2012), which may allow a more precise addition of variability.

Several running studies are available on acute influences of varied conditions, where coordination has been examined such as obstacles in the track (Stergiou, Jensen et al., 2001; Stergiou, Scholten, Jensen, & Blanke, 2001) or elastic tubes applied to the lower extremities (e.g., Haudum et al., 2012). To our knowledge, only few intervention studies exist where joint coordination was examined especially under varying conditions (e.g., Haudum, Birklbauer, & Müller, 2011a; Haudum et al., 2012b). A limited number of studies, however, have employed intervention-induced variability to maintain or regain a functional level of variability in healthy individuals in joint coupling variability (Haudum et al., 2012b), which may provide relevant insights into possible alterations due to the prevailing constraints (Hein et al., 2012). In addition, the effect of variable constraints applied in acute situations or over a longer period of time may differ, since a new and possibly more appropriate movement pattern may be developed.

In a first step and to clarify the role of a dynamic constraint in the form of elastic tubes on joint motion and joint coupling variability in a healthy population, we employed kinematic motion analyses to determine the effects of such an intervention. The elastic tubes were used to apply perturbations to the running pattern so that within movement variability is increased but the running patter is not rendered. The tubes are used to functionally achieve an optimal level of within-movement variability and to support the shaping or initiating of emergent movement patterns. Due to the sensitivity of the