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Author(s)	Noro, Kazuto; Takeichi, Asumi; Hirai, Hiroaki et al.
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Physiological Markers of Motor Improvement Following Five-month Sprint Training in Young Boys

Kazuto Noro[1], Asumi Takeichi[1], Hiroaki Hirai[1], Hideya Okamoto[2], Daisuke Kogawa[2], Chikako Kamimukai[2], Yasunori Kaneko[2], Noriyuki Tabuchi[2], Shoji Kinoshita[2], Yuta Miyajima[1], Yusuke Yashima[1], Hirokazu Kuga[1], Satoru Yamamoto[1], Naoto Yamada[1], Kazuhiro Matsui[1], Atsushi Nishikawa[1], and Hermano Igo Krebs[1,3]
[1]Graduate School of Engineering Science, Osaka University, Japan
noro@hmc.me.es.osaka-u.ac.jp, takeichi.asumi@hmc.me.es.osaka-u.ac.jp, hirai.hiroaki.es@osaka-u.ac.jp
[2]Global Research and Development Department, Mizuno Corporation, Japan
[3]Department of Mechanical Engineering, Massachusetts Institute of Technology, USA

1 Introduction

Effective sprint training has been sought by trainees, trainers, and researchers in track and field athletics. The lack of scientific evidence based on high-quality and long-term training data prevents the establishment of a theory of evidence-based practice [1]. Previous studies have reported specific designs of training and their intervention outcomes for adults [2]-[7] and children [8][9], and an exhaustive survey of existing training practices [10]; however, the physiological mechanisms underlying motor improvement remain unclear. This study aimed to identify the physiological markers of motor improvement during long-term sprint training in young boys. We investigated two motors of equilibrium point (EP)-based co-activation synergies and the concomitant virtual trajectory, hypothesizing that the development of neuromuscular coordination would explain motor improvement.

2 Materials and Methods

Ethics statement. Nine age-matched healthy Japanese boys (10/11 years old, 1.46 ± 0.08 m, 34.3 ± 5.13 kg) participated in the experiment. None of the participants reported any history of neuromuscular disorders or injuries. All participants provided written informed consent prior to participation. This study was approved by the Institutional Review Board for the Mizuno Corporation.

Experimental protocol. The participants attended sprint technique lessons for five months at Mizuno running school. The 1.5 hours weekly lessons included several athletic drills and technical instructions, focusing on specific sprint techniques, such as body posture, arm swing, and foot-ground contact. Sprint performance was assessed at the early, middle, and late stages of the five-month training program. After the warm-up exercise, the participants performed an average of five trials of a 30-m all-out sprint run on a grass track. Sufficient rest between the trials was allowed to avoid fatigue.

Measurement. Kinematics and surface electromyography data were simultaneously collected during sprinting. The examined data for both leg movements were the positions of the hip, knee, ankle, heel, and toe and the electrical activity of the gluteus maximus, iliopsoas, semitendinosus, rectus femoris, vastus lateralis, and short head of the biceps femoris muscles.

Analysis. A U.S.-patented synergy analyzer [11] was applied to estimate the EP-based co-activation synergies and the concomitant virtual trajectory in the configuration space. The virtual trajectory is regarded as a time sequence of motor commands to locate the endpoint (i.e., foot) during voluntary movement, which requires regulation and control of the skeletal system with multiple muscles.

3 Results and Discussion

EP-based co-activation synergies. Figure 1 shows the EP-based co-activation synergies of the nine participants during sprinting in the early, middle, and late stages of the five-month training program. In each ternary diagram, the left upper, right upper, and bottom axes represent the co-activation of the hip, hip, knee (bi-articular), and knee muscles, respectively. These co-activations are the components of the base unit vectors that represent the endpoint equilibria in the radial, tangential, and null directions. The population of EP-based co-activation synergies showed a drastic change with training progress, in which the EP-based co-activation synergies for radial, tangential, and null movements formed a specific relationship with their smaller variances. Interestingly, at the late stage of training, the centers of each population were located at almost the same intervals on the midline (blue dotted) of the ternary diagram. The results indicate that all nine participants achieved similar muscle coordination after five-month training.

Virtual trajectory. The concomitant virtual trajectory was developed through sprint training in the configuration space of EP-based co-activation synergies. Figure 2 shows the occurrences of the three types of virtual trajectories estimated from the nine participants' sprints at the early, middle, and late stages of training. The virtual trajectories were clustered using machine learning techniques (dynamic time warping and *k*-means clustering). As the training progressed, the occurrence of virtual trajectory C increased, whereas the occurrence of virtual trajectory A decreased. The results indicated a systematic alteration in the occurrence of different types of virtual trajectories. Figure 3 shows the three types of virtual trajectories in the task space. The remarkable feature of the improved virtual trajectory (B/C) is the earlier descent of the endpoint equilibria in the terminal swing phase. The results indicate that motor planning on prediction and preparation for the next landing was improved in the participants' sprint after training.

These findings confirm that EP-based co-activation synergies and virtual trajectory are powerful markers of neuromuscular coordination, which underlies the control of sprinting during and after training, and provide scientific evidence for sprint training at the Mizuno running school.

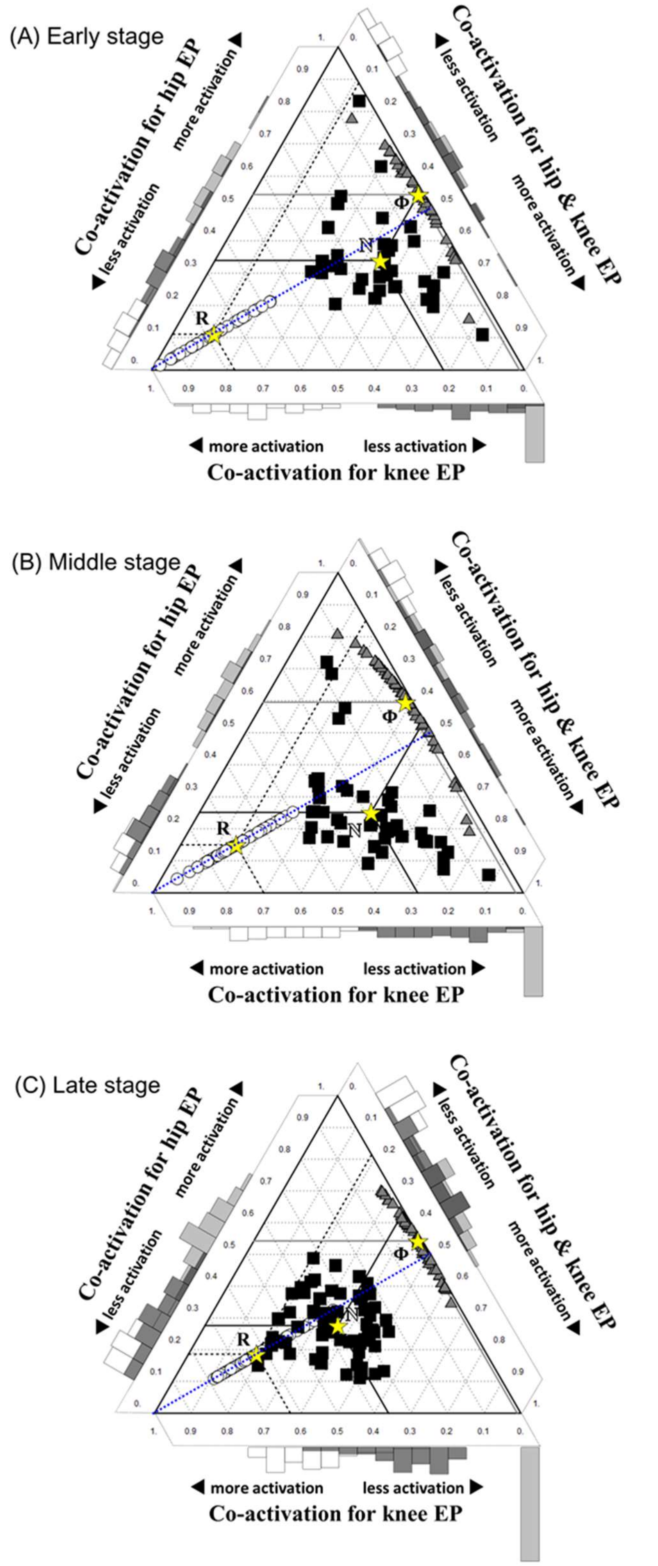

Figure 1: Change in equilibrium point (EP)-based co-activation synergies in sprinting legs of young boys during five-month training: (A) early, (B) middle, and (C) late stages. Yellow star mark indicates the center of population of the EP-based co-activation synergy for radial (circle), tangential (triangle), and null (square) movements, respectively.

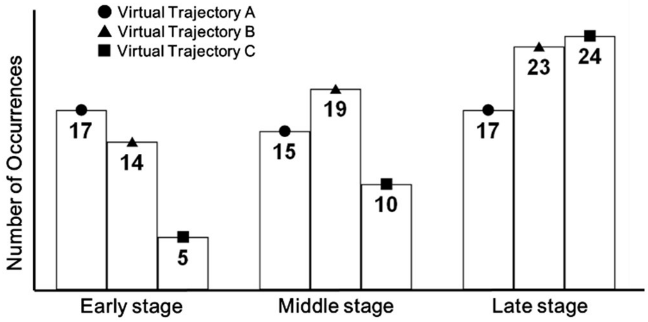

Figure 2: Occurrences of three types of virtual trajectory at the early, middle, and late stages of training. The number of occurrences of the virtual trajectory C tends to increase with the progress of training.

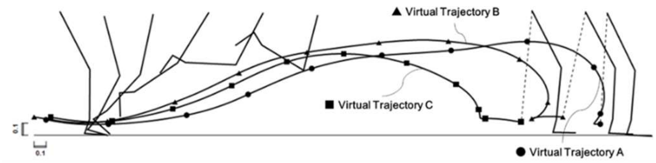

Figure 3: Three types of virtual trajectory resulting in actual leg movement of sprinting participants. The virtual trajectories of type A, B, and C correspond to those in Fig. 2.

References

[1] C. Delecluse, "Influence of Strength Training on Sprint Running Performance. Current Findings and Implications for Training," *Sports Med.*, Vol. 24, No. 3, pp. 147-156, 1997.

[2] M. C. Marques, T. J. Gabbett, D. A. Marinho, A. J. Blazevich, A. Sousa, R. van den Tillaar, and M. Izquierdo, "Influence of Strength, Sprint Running, and Combined Strength and Sprint Running Training on Short Sprint Performance in Young Adults," *Int J Sports Med.*, Vol. 36, No. 10, pp. 789-795, 2015.

[3] P. Giorgos and Z. Elias, "Effects of Whole-body Vibration Training on Sprint Running Kinematics and Explosive Strength Performance," *J Sports Sci Med.*, Vol. 6, No. 1, pp. 44-49, 2007.

[4] G. P. Paradisis and C. B. Cooke, "The Effects of Sprint Running Training on Sloping Surfaces," *J Strength Cond Res.*, Vol. 20, No. 4, pp. 767-777, 2006.

[5] A. Ross and M. Leveritt, "Long-Term Metabolic and Skeletal Muscle Adaptations to Short-Sprint Training: Implications for Sprint Training and Tapering," *Sports Med.*, Vol. 31, No. 15, pp. 1063-1082, 2001.

[6] O. Girard, A. Mendez-Villanueva, and D. Bishop, "Repeated-Sprint Ability - Part I: Factors Contributing to Fatigue," *Sports Med.*, Vol. 41, No. 8, pp. 673-694, 2011.

[7] D. Bishop, O. Girard, and A. Mendez-Villanueva, "Repeated-Sprint Ability - Part II: Recommendations for Training," *Sports Med.*, Vol. 41, No. 9, pp. 741-756, 2011.

[8] A. Chaouachi, A. B. Othman, R. Hammami, E. J. Drinkwater, and D. G. Behm, "The Combination of Plyometric and Balance Training Improves Sprint and Shuttle Run Performances More Often Than Plyometric-Only Training With Children," *J Strength Cond Res.*, Vol. 28, No. 2, pp. 401-412, 2014.

[9] D. G. Behm, A. D. Faigenbaum, B. Falk, and P. Klentrou, "Canadian Society for Exercise Physiology Position Paper: Resistance Training in Children and Adolescents," *Appl Physiol Nutr Metab.*, Vol. 33, No. 3, pp. 547-561, 2008.

[10] M. C. Rumpf, R. G. Lockie, J. B. Cronin, and F. Jalilvand, "Effect of Different Sprint Training Methods on Sprint Performance Over Various Distances: A Brief Review," *J Strength Cond Res.*, Vol. 30, No. 6, pp, 1767-1785, 2016.

[11] F. Miyazaki, et al., Motion Analysis Apparatus, Method for Analyzing Motion, and Motion Analysis Program, US10631751B2, 2020.