Influence of pole carriage on sprint mechanical properties during pole vault run-up

J. Frère∗, H. Sanchezb, S. Homo, G. Rabita, JB. Morin and J. Cassirame

∗EA 3450 DevAH, Faculté des Sciences du Sport, Université de Lorraine, Nancy, France; b Fédération Française d’Athlétisme, Paris, France; †EA 7370 SEP, Unité Recherche, Institut National du Sport, de l’Expertise et de la Performance, Paris, France; ‡Université Côte d’Azur, LAMHESS, Nice, France; ‡EA 4660 CSS, Plateforme EPSI, Université Bourgogne-Franche Comté, Besançon

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1. Introduction

Pole vault performance is highly correlated with the final running velocity of the athlete at take-off (Frère et al. 2010). To achieve top running velocity, the athlete has to develop a large forward acceleration, which is related to the ability to produce and apply a high amount of impulse onto the ground (Rabita et al. 2015). Although it is well known that carrying a pole impairs horizontal velocity output (Gros & Kunkel 1990), only few studies investigated the underlying mechanisms explaining this loss of velocity. For instance, Frère et al. (2009) found in novice athletes a reduction of maximal hip and knee flexion during 30-m sprints with pole carriage that induced a decrease in stride length, and thus, a lower horizontal velocity. However, mechanical changes due to the pole carriage and for a higher level of expertise remain unexplored.

This study aimed to characterise the changes in horizontal force- and power-velocity relationships induced by pole carriage, by means of a validated simple field model based on a macroscopic inverse dynamic approach (Samozino et al. 2016).

2. Methods

2.1. Athletes

Seventeen experienced pole vaulters (10 women, height: 167 ± 7 cm, body mass: 57 ± 6 kg, personal best: 4.03 ± 0.22 m; 7 men, height: 175 ± 2 cm, body mass: 65 ± 3 kg, personal best: 5.08 ± 0.16 m) volunteered to participate in this study.

2.2. Protocol

After an appropriate warm-up, athletes performed 2 maximal accelerations without pole and 2 with pole carriage in a random order with 5 min of passive recovery between sprints. According to their usual run-up length during competition, men sprinted over a 40-m distance, while women sprinted over a 30-m distance. The athletes were instructed to run as fast as possible and to keep a constant pole-ground angle throughout the trial. The pole-ground angle corresponded to the one used in the first half of the usual run-up. Each athlete used her/his own vaulting pole meeting the imposed length and mass characteristics: 4.30 m for women and 4.90 m for men; 1.8 kg for women and 2.1 kg for men. All athletes were free of injury during this measurement session.

2.3. Measurements and data processing

For each sprint trial, a radar gun Stalker Pro II (Stalker ltd, Plano, United States) was placed behind the athlete in the sprint direction at a 1.4 m height and allowed measuring the instantaneous horizontal velocity of the athlete (sampling rate of 46.9 Hz). This data flow was integrated into MookyStalker software (Matsport, Saint-Ismier, France) to export the raw velocity-time data, which were processed offline using Samozino’s model (2016).

Briefly, the velocity-time data were fitted by an exponential function, which was then derived to estimate the net horizontal anteroposterior ground reaction force and the power output in the horizontal direction. From all of these mechanical data over time, individual linear force-velocity relationships were then extrapolated to calculate the force-velocity profile (SFV), which corresponded to the slope of the linear model, theoretical maximal force (F0, in N/kg) and velocity (V0, in m/s) capabilities. Finally, the power-velocity relationships were extrapolated by a 2nd order polynomial function to calculate the maximal power output (Pmax, in W/kg). These relationships and
4. Conclusions

Pole carriage during sprinting induces a large decrease in power output due to simultaneous impairment in force and velocity capabilities.

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References

Frère J, Chollet D, Tourny-Chollet C. 2009. Assessment of the influence of pole carriage on sprint kinematics: A case study of novice athletes. Int J Sports Sci Eng. 3:3–10.

Frère J, L’Hermette M, Slawinski J, Tourny-Chollet C. 2010. Mechanics of pole vaulting: a review. Sports Biomech. 9:123–138.

Gros H, Kunkel V. 1990. Biomechanical analysis of the pole vault. In: Brüggemann G-P, Glad B, editors. Sci Res Proj Games 24th Olymp – Seoul 1988 Final Rep. IAAF: Monaco; p. 219–260.

Hopkins WG, Marshall SW, Batterham AM, Hanin J. 2009. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 41:3–13.

Rabita G, Dorel S, Slawinski J, Sàez-de-Villarreal E, Couturier A, Samozino P, Morin J-B. 2015. Sprint mechanics in world-class athletes: a new insight into the limits of human locomotion. Scand J Med Sci Sports. 25:583–594.

Samozino P, Rabita G, Dorel S, Slawinski J, Peyrot N, Saez de Villarreal E, Morin J-B. 2016. A simple method for measuring power, force, velocity properties, and mechanical effectiveness in sprint running. Scand J Med Sci Sports. 26:648–658.