ELEVATED TRACK IN POLE VAULT, WHAT ADVANTAGE FOR RUN-UP DETERMINANTS OF PERFORMANCE?

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The aim of the present study was to compare high-level pole vault performances set in standard versus elevated tracks during official competitions, with a specific focus on the mechanical determinants of the run up phase such as speed, contact time, step frequency, lower-limb stiffness and take off position. The main variables that were significantly correlated to a benefit from elevated tracks on run-up speed were speed on a normal track, step frequency, percent change in contact time and step frequency. The use of indoors elevated track in high-level to world-class athletes did not result in systematic increase in the main performance determinant, i.e. run-up speed. However, the individual changes analysis shows that slower athletes with lower step frequency are those who benefit the most from the use of elevated track.

KEY WORDS: pole vault, elevated track, speed, performance.

INTRODUCTION: Indoors track and field conditions are well calibrated and performances could be easily compared. Nevertheless, indoors pole vault, long jump, or triple jump are sometimes practiced on elevated track. Performances achieved in such conditions have been debated, especially around a possible beneficial effect of the elevated track on run up mechanics, especially in pole vault. The comparison of all-time best performances in pole vault reveals that the current 3 best performers realized their personal best on elevated track while the 4th to 9th performers did it on a normal track. Obviously, those findings are very difficult to interpret, because some normal track performances were set outdoors, where environmental conditions (e.g. wind, rain, temperature) can significantly facilitate or limit performance. Furthermore, not all athletes systematically participate to indoor competitions. To our knowledge, no study compared the run up determinants of pole vault performance between competitions performed on elevated and normal track. The aim of the present study was to compare high-level pole vault performances set in standard versus elevated tracks during official competitions, with a specific focus on the mechanical determinants of the run up phase such as speed, contact time, step frequency, lower-limb stiffness and take off position.

METHODS: The data used in this study were collected during the scientific follow-up of the French national elite pole-vaulters 2014 and 2015. The 10 subjects (age: 25.9 ± 4.0 years ; height: 1.79 ± 0.05 m ; body weight: 71.4 ± 6.5 kg) were highly trained pole-vault male specialists with personal bests ranging from 5.55 to 6.16 m. Data from two competitions were compared: the first performed on an elevated track and the second on a normal track 3 or 5 weeks after. All measurements were performed without interaction with athletes and therefore did not influence performance.
During the two pole-vault competitions, various parameters that were shown to be correlated to performance (Vaslin 1993 ; Linthorne and Weetman 2012) were measured in the same

conditions. Twenty meters of Optojump Next (Microgate, Bolzano, Italy) were placed on the track at the end of the run-up, in order to record running spatio-temporal parameters: contact time, flight time and position of the feet. This tool was synchronized with a Radar device (Stalker Radar Pro II, Plano, United States) placed behind the reception mat in order to record continuously the inbound running speed during the approach (Figure 1). Data were computed to provide information as the take-off position, position at six steps before take-off, and average speed from 20 to 15m, 15 to 10m, and 10 to 5m away from the box. Vertical and lower-limb stiffness were calculated using the since-wave method proposed by Morin et al. (2005) on the basis of running speed, contact and flight time, and subjects body mass and lower-limb length. Step frequency, step length, contact time, flight time and stiffness were averaged over the four steps before the last two ones in order to avoid taking into account the mechanics alterations related to jump adjustment occurring during the last two steps.
Statistical analysis was performed using Sigmaplot software v12 (SAX Software, Karlsruhe, Germany): comparison of parameters between each condition was performed with one-way ANOVA, and correlations between parameters and average approach speed (10-5m from the box), since the latter parameter was considered as the most important determinant of pole vault performance (Linthorne and Weetman 2012 ; Frère and al. 2010). Significant threshold was set at $P < 0.05$.

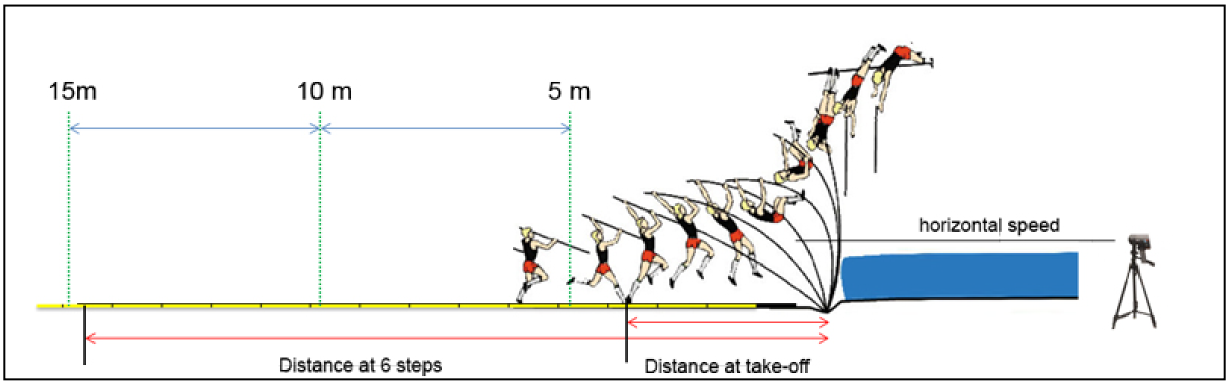

Figure 1. Measurements design

RESULTS: Excepted for two athletes, all subjects improved their average approach speed on the elevated track. Among the parameters shown in Table 1, significant difference was found between both conditions for flight time ($P = 0.029$) and speed from 15 to 10m to the box (0.017), while a trend towards a higher speed at 20 to 15 m ($P = 0.109$) was observed.

	Take-off pos. (m)	*Dist at 6 steps (m)*	*S 20-15m ($m.s^{1}$)*	*S 15-10m ($m.s^{-1}$)*	*S 10-5m ($m.s^{1}$)*	*Step. Lgt (m)*	*Step freq ($p.s^{1}$)*	*C. Time (ms)*	*F. Time (ms)*	*Vert. Stif (kN/m)*	*LL Stif (kN/m)*
NT	**3.76**	**16.41**	**8.44**	**8.79**	**9.11**	**2.09**	**4.19**	**0.118**	**0.123**	**85.68**	**12.64**
SD	*0.28*	*0.57*	*0.44*	*0.36*	*0.35*	*0.17*	*0.21*	*0.007*	*0.010*	*12.54*	*2.74*
ET	**3.79**	**16.37**	**8.64**	**8.94***	**9.18**	**2.10**	**4.23**	**0.118**	**0.118***	**85.42**	**12.19**
SD	*0.26*	*0.71*	*0.46*	*0.37*	*0.26*	*0.08*	*0.20*	*0.007*	*0.014*	*10.18*	*3.06*

Table1. Run-up parameters measured on Normal (NT) and Elevated track (ET). Results are mean±SD.

Since the results showed highly inter-individual variability in the adaptations to elevated tracks, the correlations between percent changes in run-up speed on elevated track were plotted against speeds on normal track, step frequency, percent changes in contact and flight time, vertical and lower limb stiffness on elevated track (Figure 2). This analysis shows that the main variables that were significantly correlated to a benefit from elevated tracks on run-up speed were speed on a normal track, step frequency, percent change in contact time (all negatively correlated) and step frequency (positively correlated).

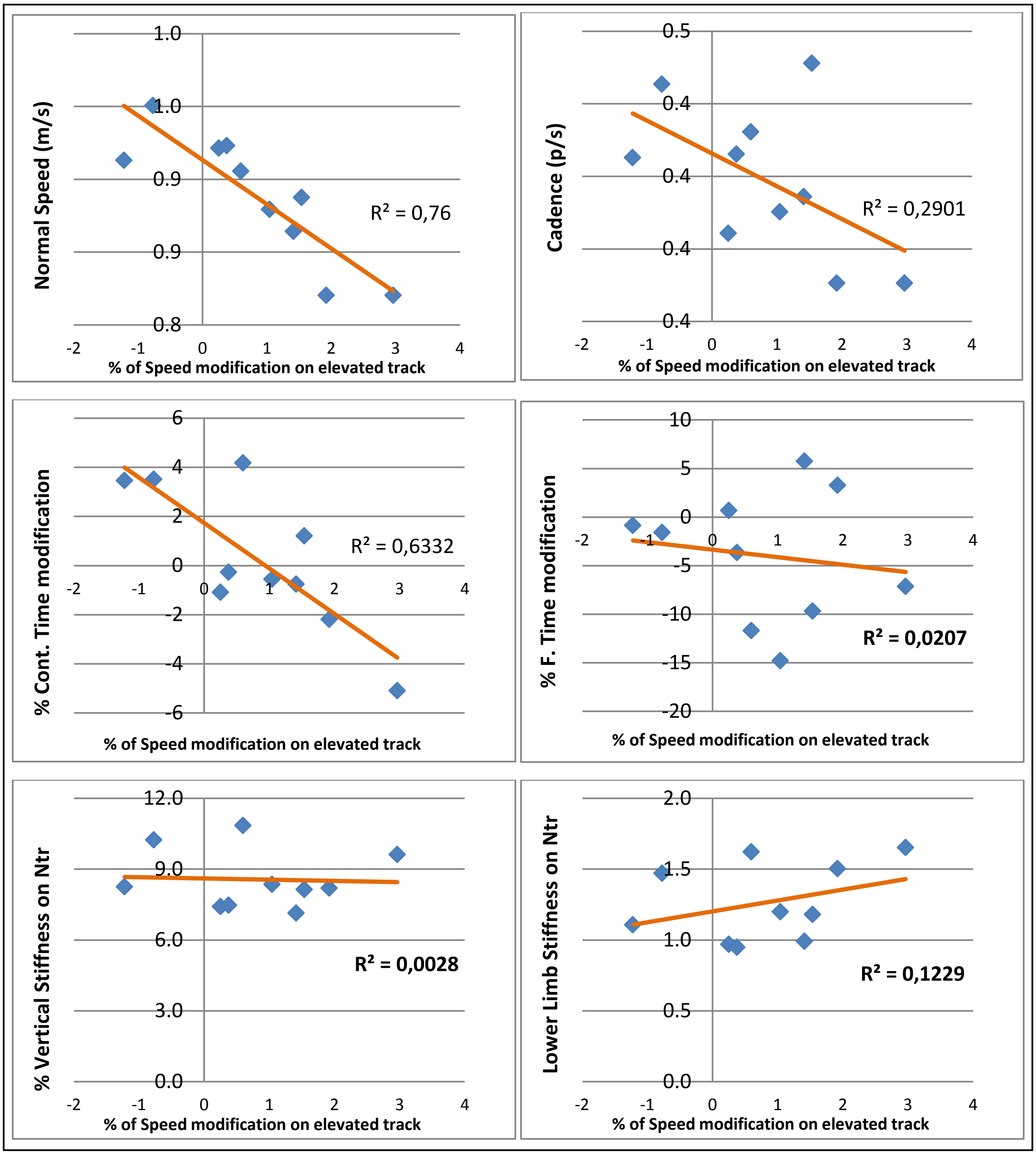

Figure 2. Relation between speed gain on elevated track and speed on normal track, step frequency, % modification of contact and flight time, vertical and lower limb stiffness

DISCUSSION: The main result of this study is that, compared to normal track, the elevated track typically used in some indoors official competition only induce significant changes in lower flight time and approach speed but do not affect significantly all run-up mechanics and performance, in a group of high-level to world-class athletes. However, a high inter-subjects variability was observed as to the adaptations to the elevated track. When investigating in further details the individual changes in run-up speed between the two track conditions (Figure 2), we observed that positive changes in run-up speed (i.e. likely improved performance, all other things being equal) were significantly correlated negatively with normal track speed, step frequency and ability to reduce contact time on the elevated track. In other words, the athletes who had the slowest speed on a normal track, and/or the lowest step frequency (these two variables are closely related) were also those who benefited the most from the use of an elevated track. In addition, as maximal speed is likely limited by the ability to increase maximal step frequency (Rabita and al. 2015), fastest athletes with higher step frequency might not be able to further increase their step frequency / speed on an elevated track, whereas slower ones do. Further support to this hypothesis is that all other run-up parameters (step length, take-off position, and distance at six steps) were unchanged between conditions. Another variable positively correlated with speed increase on elevated track is the ability to reduce contact time while running on the elevated track. This might be related to the ability of athletes to modulate their lower limb stiffness towards a higher stiffness on the elevated track. However, further investigations are needed to clarify this point since our measurements did not allow to distinguish between the subjects' lower limb stiffness and the stiffness of the running track. It has been shown that both interact (Ferris and al 1998) and that subjects increase their lower limb stiffness when running on a more compliant surface (which is typical from elevated tracks).

CONCLUSION: this study shows that on average, the use of indoors elevated track in high-level to world-class athletes did not result in systematic increase in the main performance determinant, i.e. run-up speed. However, the individual changes analysis shows that slower athletes with lower step frequency are those who benefit the most from the use of elevated track. This information may be of interest to the athletics governing bodies and competition organizers since elevated track likely give an unfair advantage to slower athletes, which might level competitions, and influence personal best performances.

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