

Research article

STARTING BLOCK PERFORMANCE IN SPRINTERS: A STATISTICAL METHOD FOR IDENTIFYING DISCRIMINATIVE PARAMETERS OF THE PERFORMANCE AND AN ANALYSIS OF THE EFFECT OF PROVIDING FEEDBACK OVER A 6-WEEK PERIOD

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Received: 08 November 2004 / Accepted: 21 March 2005 / Published (online): 01 June 2005

ABSTRACT

The purpose of this study was twofold: (a) to examine if kinetic and kinematic parameters of the sprint start could differentiate elite from sub-elite sprinters and, (b) to investigate whether providing feedback (FB) about selected parameters could improve starting block performance of intermediate sprinters over a 6-week training period. Twelve male sprinters, assigned to an elite or a sub-elite group, participated in Experiment 1. Eight intermediate sprinters participated in Experiment 2. All athletes were required to perform three sprint starts at maximum intensity followed by a 10-m run. To detect differences between elite and sub-elite groups, comparisons were made using *t*-tests for independent samples. Parameters reaching a significant group difference were retained for the linear discriminant analysis (LDA). The LDA yielded four discriminative kinetic parameters. Feedback about these selected parameters was given to sprinters in Experiment 2. For this experiment, data acquisition was divided into three periods. The first six sessions were without specific FB, whereas the following six sessions were enriched by kinetic FB. Finally, athletes underwent a retention session (without FB) 4 weeks after the twelfth session. Even though differences were found in the time to front peak force, the time to rear peak force, and the front peak force in the retention session, the results of the present study showed that providing FB about selected kinetic parameters differentiating elite from sub-elite sprinters did not improve the starting block performance of intermediate sprinters.

KEY WORDS: Feedback, kinetic, kinematic, performance, sprint.

INTRODUCTION

The sprint start is a complex motor task characterized by large forces exerted in the horizontal direction and by the ability to generate these forces in a short time period (Hafez et al., 1985; Harland et al., 1995). The starting position is an important aspect of sprint performance (Schot and Knutzen, 1992), from which the location of the center of mass (CM) and an horizontal CM velocity have been identified as descriptors of a good starting block performance (Mero, 1988). Several other kinetic and kinematic variables such as the rear peak force, the block time, the block leaving velocity and the block leaving acceleration, have been reported as possible parameters influencing starting block performance (Hafez et al., 1985; Harland et al., 1995). Most of these suggestions, however, lacked statistical support. The first part of this study aimed to use the linear discriminant analysis (LDA) to identify which kinetic and kinematic parameters differentiate most the elite from sub-elite sprinters in a starting block task. Discriminant analysis is a useful tool for detecting variables that could distinguish group differences and for classifying subjects into different groups with a better than chance accuracy. The intent of this analysis is to assess which variables are determinants of starting block performance in order to provide athletes with proper training feedback (FB).

In the early sixties, several researchers have stamped FB as being the most important variable affecting performance and learning. It was suggested that FB could increase the performance of a complex laboratory motor task and the rate of improvement on new tasks, enhance performance on overlearned tasks, and make tasks more interesting (Bilodeau and Bilodeau, 1961; Sage, 1984). Based on these assumptions, sprint coaches integrated FB into training sessions to refine athletes' movement patterns. To date, multiple FB sessions on motor task performance have been conducted mainly on unique sessions (Harland et al., 1995; McClements et al., 1996; Mendoza and Schollhorn, 1993; Sanderson et al., 1991; Smith et al., 1997; Smith and Eason, 1990; Winstein and Schmidt, 1990), have not included skill level as a controlled variable (Kernodle and Carlton, 1992; Smith et al., 1997; Viitasalo et al., 2001; Winstein and Schmidt, 1990; Wulf et al., 1998; Wulf and Weigelt, 1997), and have not monitored the training context (environment in which the training is conducted) (Kernodle and Carlton, 1992; Smith et al., 1997; Smith and Eason, 1990; Viitasalo et al., 2001; Winstein et al., 1994; Winstein and Schmidt, 1990; Wulf et al., 1999). It would be interesting, thus, to observe in a training context whether providing FB

during multiple training sessions could improve starting block performance in intermediate sprinters.

The purpose of this study was twofold: (a) to examine if kinetic and kinematic parameters of the sprint start could differentiate elite from sub-elite sprinters and, (b) to investigate whether providing feedback (FB) about selected parameters could improve the starting block performance of intermediate sprinters over a 6-week training period. We hypothesized that providing FB from performance discriminating parameters to intermediate sprinters would improve their starting block performance.

EXPERIMENT 1

METHODS

Subjects

Twelve male sprinters participated in Experiment 1. At the time of testing, all sprinters were in their competitive phase. Subjects gave their written informed consent, in compliance with Laval University's Ethics Committee regulations, to participate in this experiment. Prior to the study, all subjects had achieved Athletics Canada Qualifying Standards. Based on the Track and Field Provincial Association Board criteria and on their best performance in 100 m (elite <10.70 sec; sub-elite >10.70 sec and <11.40 sec), six athletes were assigned to the elite group and six to the sub-elite group. Sprint performance and physical characteristics of the subjects are presented in Table 1.

Task, apparatus, and procedure

The data were obtained by setting the experimental starting block on the track during the 2000 Provincial Senior Track and Field Championships in Québec city. Sprinters were asked to perform three sprint starts at maximum speed using a conventional starting block and run 10 m. Hand switches started a millisecond timer and a break in the light beam of photoelectric cells (located 10 cm above the floor and 4 m from the start line) stopped the time. Perpendicular forces to the footplates were recorded by an instrumented starting block. Signals from the fixed strain gauges were conditioned and amplified (Ectron E563H, Don Mills, Ont) prior to recording at 1 kHz (12-bit A/D). The start signal was given by a gun shot and was online recorded at 1 kHz. To avoid fatigue, a 4 min rest period was given between trials. For the kinematic analysis, video records were taken at 30 frames·s⁻¹ with six video cameras. Three cameras were placed on each side of the subject to capture the start and the first step. The

Table 1. Physical characteristics and performance of the subjects in Experiment 1.

Subjects	Age (yrs)	Height (m)	Body Mass (kg)	100-m record time (s)	Events
Elite					
1	21	1.57	62.5	10.58	100m - 200m
2	25	1.87	91.9	10.30	100m - 200m
3	18	1.68	74.0	10.45	100m
4	19	1.70	65.2	10.56	100m - 200m
5	23	1.79	75.7	10.36	100m - 110m hurdles
6	22	1.76	75.4	10.51	100m
Mean (\pm SD)	21.3 (2.6)	1.72 (.1)	74.1 (10.3)	10.46 (.11)	
Sub-elite					
7	26	1.82	84.8	10.85	100m - 200m
8	19	1.77	67.9	11.29	100m
9	30	1.74	70.0	10.90	100m 200m
10	21	1.75	68.6	11.30	100m 200m
11	23	1.85	74.0	11.37	100m - 110m hurdles
12	22	1.87	86.1	10.73	100m
Mean (\pm SD)	23.5 (3.9)	1.80 (.05)	75.2 (8.2)	11.07 (.30)	

environment was calibrated with a structure of known dimensions. Passive reflective markers were bilaterally placed on the skin of the subjects: feet (fifth metatarsal phalangeal joint), ankles (external malleolus), knees (lateral femoro-tibial joint), hips (greater trochanter and superior anterior iliac spine), shoulders (acromio-clavicular joint), elbows (lateral epicondyle), wrists (styloid process of ulna), and on the head (zygomatic process and glabella). A final marker was placed on the right border of the track as a reference point. Video records were software synchronized by turning on a light emitting diode that could be captured by all cameras. A voltage pulse was sent simultaneously to the A/D board to synchronize kinetic and kinematic data. All video records were captured digitally (Adobe Premiere).

Data analysis

In each frame, every marker was digitalized with software allowing determining precisely their centroid position. The 3D position and velocity of the total body CM was estimated using a 5-segment anthropometric model (foot, shank, thigh, trunk, neck and head, and arm) based on Dempster's estimates of the segment weight and segment mass-center location (Dempster, 1955). Displacement signals were filtered (second-order low-pass Butterworth filter with a 7 Hz cutoff frequency with forward/backward passes to eliminate phase shift) and time derivatives of the linear displacements were then computed with a finite difference technique.

All kinetic parameters were analyzed using custom made software (MATLAB, MathWorks Inc., Natick, MA). Force curves were low-pass filtered in the same way as the aforementioned displacement

signals. The rate of change of force production (first derivative of the force curves) was calculated to precisely identify force onsets. Figure 1 shows an example of the recorded forces. The following parameters were determined from each trial: (a) reaction time [RT], defined as the time from the gun signal to the first detectable change of pressure in the instrumented blocks; (b) front force duration [FFD], defined as the time between the front force onset and the front force offset; (c) rear force duration [RFD], defined as the time between the rear force onset and the rear force offset; (d) total block time [TBT], defined as the time between the force onset and the force offset; (e) time to front peak force [TFPF], defined as the time between the force onset and the front peak force; (f) time to rear peak force [TRPF], defined as the time between the force onset and the rear peak force; (g) front peak force [FPF], defined as the maximal front force value; (h) rear peak force [RPF], defined as the maximal rear force value; (i) delay between rear and front force onset [DRF onset], defined as the onset time delay between both forces, and (j) delay between end of rear and front force offset [DRF offset], defined as the time between the front force offset and the rear force offset. The 4 m run time was also recorded.

Statistical analysis

To detect differences between groups, comparisons were made using *t*-tests for independent samples. Variables yielding a significant group difference were retained for the LDA, which was performed to determine whether elite and sub-elite athletes differed with regard to the mean of variables entered into the model. Statistical analyses were performed using Statistica 5.5 (Statsoft Inc., Tulsa, OK).

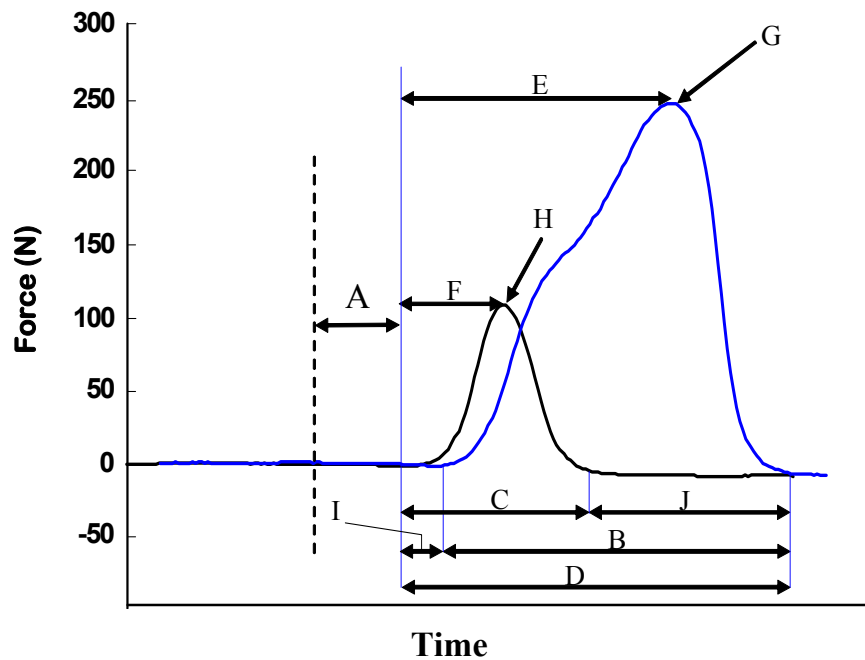


Figure 1. Typical kinetic parameters: (A) reaction time, (B) front force duration, (C) rear force duration, (D) total block time, (E) time to front peak force, (F) time to rear peak force, (G) front peak force, (H) rear peak force, (I) delay between rear and front force onset, and (J) delay between end of rear and front force offset.

Results are expressed as mean and standard deviation (\pm SD). Significant difference was set at $p < 0.05$.

RESULTS

Table 2 shows mean values and SD of kinetic and kinematic parameters for both groups. For each subject, the three starting block trials were averaged. The *t*-test analysis showed that ten kinetic and kinematic parameters yielded a significant group difference. All ten variables were included in the LDA to determine to which group each observation most likely belonged. The forward stepwise LDA reduced the model to the following four variables: (1) delay between end of rear and front force offset (DRF offset), (2) rear peak force (RPF), (3) total block time (TBT), and (4) time to rear peak force (TRPF). Then, the following discriminant functions were obtained:

$$D_{1(\text{elite})} = -0.457 \times \text{DRFoffset} - 0.320 \times \text{RPF} + 1.649 \times \text{TBT} - 1.249 \times \text{TRPF}$$

$$D_{2(\text{sub-elite})} = -0.488 \times \text{DRFoffset} - 0.414 \times \text{RPF} + 1.875 \times \text{TBT} - 1.492 \times \text{TRPF}$$

The LDA classification functions showed that the elite group presented the best classification (100%) whereas the sub-elite group presented three individuals erroneously classified as elite (83%).

The total LDA classification reached 92% which is considered as an acceptable value. Lambda values represent the unique contribution of the respective variable to the discriminatory power of the model. The latter showed that the DRF offset was the most discriminant variable ($\lambda=0.664$, $F_{(1,25)}=12.677$, $p=0.001$), followed by the RPF ($\lambda=0.495$, $F_{(2,24)}=12.233$, $p=0.0002$), the TBT ($\lambda=0.442$, $F_{(3,23)}=9.661$, $p=0.0002$), and finally the TRPF ($\lambda=0.296$, $F_{(4,22)}=13.077$, $p=0.0001$). Overall, this suggests that the LDA allowed differentiation of the elite group from the sub-elite group. The DRF offset was the main determinant of starting block performance among the 10 selected parameters for the sprinter sample and could be considered as a good indicator of sprint start performance since it directly affects the TBT, which was previously identified as an important starting block factor.

EXPERIMENT 2

The purpose of Experiment 2 was to examine whether providing specific FB about the identified parameters of Experiment 1 (delay between end of rear and front force offset, DRF offset; rear peak force, RPF; total block time, TBT; and time to rear peak force, TRPF) could enhance the performance of intermediate sprinters. Our hypothesis was that providing FB in a field situation would help intermediate sprinters to improve their starting block performance and consequently their 4 m run time.

Table 2. Summary of kinetic and kinematic parameters of experiment 1. Data are means (\pm SD).

Parameters	Units	Elites	Sub-elites
Reaction Time (RT)	ms	172 (30)*	194 (26)
Front Force Duration (FFD)	ms	370 (18)*	405 (40)
Rear Force Duration (RFD)	ms	370 (18)	268 (58)
Total Block Time (TBT)	ms	399 (21)*	422 (33)
Time to Front Peak Force (TFPF)	ms	216 (42)	260 (39)
Time to Rear Peak Force (TRFP)	ms	124 (17)*	119 (20)
Front Force at Hands onset (FFH onset)	N	1548 (333)	1440 (118)
Rear Force at Hands onset (RFH onset)	N	1274 (108)	1303 (166)
Front Peak Force (FPF)	N	1685 (490)	1735 (333)
Rear Peak Force (RPF)	N	1430 (431)*	940 (255)
Delay between Rear and Front force onset (DRF onset)	ms	26 (17)	22 (34)
Delay between end of Rear and Front force offset (DRF offset)	ms	140 (26)*	173 (23)
Mean First Step Velocity (FSV)	cm·s ⁻¹	188 (15)*	167 (17)
Mean Second Step Velocity (SSV)	cm·s ⁻¹	220 (11)	206 (25)
First Step peak Acceleration (FSA)	cm·s ⁻²	1132 (76)	1278 (182)
Second Step peak Acceleration (SSA)	cm·s ⁻²	942 (77)	859 (92)
CM Velocity at Rear offset (CMVR offset)	cm·s ⁻¹	328 (19)	312 (30)
CM Velocity at Front offset (CMVF offset)	cm·s ⁻¹	239 (25)	219 (32)
CM Acceleration at Hands onset (CMAH onset)	cm·s ⁻²	1807 (201)*	1606 (158)
CM peak Acceleration at Front offset (CMAF offset)	cm·s ⁻²	1161 (220)*	1036 (273)
CM peak Acceleration at Rear offset (CMAR offset)	cm·s ⁻²	1149 (193)*	1047 (229)

* Significantly different at $p \leq 0.05$.

METHODS

Subjects

Eight intermediate sprinters (4 males and 4 females) participated in the study, none of which had been included in Experiment 1. All subjects gave their written informed consent, in compliance with Laval University's Ethics Committee regulations. They were active athletes from a local track and field club and had been running either at the provincial or national level for a period ranging from 2 to 6 years. All the subjects maintained their habitual training and competition schedule throughout the study, which took place during the University indoor track and field season. Sprint performance and physical characteristics of these subjects are presented in Table 3.

Task, apparatus, and procedure

The task and apparatus were identical to that used in Experiment 1 as well as the collection of kinetics variables. Since no kinematic parameter arose from the LDA model (Experiment 1), only kinetic parameters were collected for Experiment 2. Subjects were tested once a week for 12 consecutive weeks. Data were acquired during the physical preparation and the competitive periods (see Figure 2 in Appendix). Six control sessions without kinetic FB (N-FB) were conducted during the specific preparatory phase (Figure 2). During this period, the subjects still received instructions provided by their coach. The following six sessions, corresponding to the competition phase, were enriched by kinetic FB (three starts, once a week). Subjects were allowed

Table 3. Physical characteristics and performance of intermediate sprinters in Experiment 2.

Subjects	Gender	Age (yrs)	Height (m)	Body Mass (kg)	60-m record time (s)	Disciplines
1	Man	23	1.87	77.0	7.21	60-300-400 m
2		23	1.73	70.8	7.19	60 m
3		20	1.64	64.0	7.02	60 m
4		15	1.73	64.0	7.44	60-100-200 m
5	Woman	20	1.68	52.0	8.31	60-100 mH
6		20	1.58	48.5	7.79	60-100-200-400 m
7		16	1.60	48.0	7.93	60-100-200 m
8		14	1.63	47.0	7.96	60 mH - 200 m
Mean (\pm SD)		18.9 (3.5)	1.68 (9.1)	58.9 (11.6)	7.60 (.46)	

to examine on a computer screen the force-time curves just exerted in the starting block. Prior to the first kinetic FB session, subjects were given a theoretical session about kinetic measurements in the starting block. For all FB sessions, subjects were encouraged to use visual information from the computer screen to; reduce the delay between end of rear and front force offset (DRF offset), to increase the rear peak force (RPF), and to reduce the total block time (TBT), representing discriminant variables obtained from Experiment 1. An experimenter helped the subjects to interpret the signals in order to make sure they understood perfectly the FB. Finally, all subjects underwent a retention session (without FB) 4 weeks after the twelfth session.

Statistical analysis

The statistical analysis included N-FB sessions (from the 1st to the 6th session), the FB sessions (from the 7th to the 12th session), and the retention (the 13th session). A one-way analysis of variance with repeated measures on the factor session (13 sessions) was used to detect differences in kinetic parameters. Significant *F* - values were followed by a *post-hoc* comparison using Tukey's HSD test. Moreover, simple linear regression analysis was used to determine relationship between strength training density and forces applied on the blocks. This was performed to ensure that block force improvements were not due to strength training (see Figure 2 in Appendix). Statistical analysis was performed with Statistica 5.5 (Statsoft Inc., Tulsa, OK). Results are expressed as mean and standard deviation (\pm SD). Significant difference was set at $p < 0.05$.

RESULTS

Table 4 presents means for the N-FB sessions (1 and 6), FB sessions (7 and 12), and R (retention) session. For all kinetic variables, no difference was observed between N-FB sessions and FB sessions and no significant improvement was observed for the 4-m run time. On the other hand, three of these kinetic variables differed significantly between the R session and the other sessions. We observed in retention: (a) a decreased in TFPF ($p < 0.05$) (b) a decreased in TRPF ($p < 0.05$), and (c) an improvement in FPF ($p < 0.05$). No significant relationship was found between strength training density and forces applied on starting blocks.

DISCUSSION

In Experiment 1, the linear discriminant analysis (LDA) allowed the identification of four kinetic

parameters differentiating elite from sub-elite sprinters. These parameters were responsible for the difference in starting block performance and of the overall sprint performance (as defined by the sprinters' personal best time). In spite of a small sample size, the group differences were better than chance accuracy because Lambda values were relatively high. To the best of our knowledge, it is the first time that an approach using LDA has been used to identify parameters that could explain starting block performance. Although statistical tools used in this study are mainly descriptive, they highlighted differences between elite and sub-elite sprinters. The delay between the end of rear and front force offset (DRF offset) was the main determinant of the starting block performance among the 10 selected parameters for the sprinter sample. It is surprising that this variable has never been considered as a good indicator of sprint start performance since it directly affects the total block time (TBT), which was previously identified as an important starting block factor. Harland and Steele (1997) showed that skilled sprinters exhibited shorter TBT compared to their less skilled counterparts. Moreover, the elite athletes of our study exhibited a smaller force difference between the rear and the front leg than the sub-elite sprinters (16% vs. 46%). This suggests that faster sprinters optimized their force production on the blocks. Although results of Experiment 1 showed that elite as well as sub-elite sprinters reached higher front peak force (FPF) than rear peak force (RPF), the former always displayed higher RPF than the latter, confirming Harland and Steele's report (1997). Other authors also have observed higher RPF than FPF in skilled sprinters (Guissard and Duchateau, 1990; Harland et al., 1995; Natta and Breniere, 1998). This certainly explains why a group difference was observed for RPF and the time to rear peak force (TRPF). These results suggest that better sprinters have developed specific motor patterns adapted to the sprint task and consequently have developed a greater rate of force development (explosiveness) than their counterparts allowing a better performance.

The purpose of Experiment 2 was to examine whether providing FB over a 6-week period could enhance the performance of intermediate sprinters. Our hypothesis was that providing FB in a field situation would help intermediate sprinters to improve their starting block performance and consequently their 4 m run time. The main finding of this experiment demonstrated that 6 sessions with FB did not modify any of the variables measured. Interestingly, three variables showed an improvement but at the retention session only (shorter TRPF and TFPF as well as greater FPF).

Table 4. Summary of kinetic parameters and 4 m run time of Experiment 2. Data are means (\pm SD).

Parameters	Units	N-FB sessions		FB sessions		R session
		1	6	7	12	13
Reaction Time (RT)	ms	177 (9)	182 (11)	186 (12)	177 (16)	183 (22)
Front Force Duration (FFD)	ms	431 (25)	420 (28)	425 (21)	433 (12)	438 (24)
Rear Force Duration (RFD)	ms	265 (21)	260 (18)	278 (34)	270 (14)	273 (42)
Total Block Time (TBT)	ms	448 (27)	442 (32)	447 (16)	447 (17)	449 (29)
Time to Front Peak Force (TFPF)	ms	392 (30)	393 (32)	392 (28)	387 (30)	299 (26) *
Time to Rear Peak Force (TRPF)	ms	219 (7)	228 (20)	226 (14)	223 (21)	137 (36) *
Front Peak Force (FPF)	N	446 (91)	514 (191)	535 (157)	563 (182)	596 (181) *
Rear Peak Force (RPF)	N	385 (101)	414 (135)	465 (134)	421 (162)	458 (175)
Delay between Rear and Front force onset (DRF onset)	ms	21 (23)	23 (24)	22 (18)	14 (5)	17 (10)
Delay between end of Rear and Front force offset (DRF offset)	ms	180 (18)	181 (25)	180 (16)	177 (16)	174 (22)
Four metre running time (4 m run time)	s	1.25 (.05)	1.26 (.05)	1.26 (.04)	1.25 (.04)	1.25 (.04)

* Significantly different at $p \leq 0.05$.

Despite these improvements, however, the 4 m run time remained constant.

Many authors have reported a positive FB effect on the learning of a complex task (McClements et al., 1996; Mendoza and Schollhorn, 1993; Sanderson et al., 1991; Smith et al., 1997; Vickers et al., 1999; Winstein and Schmidt, 1990; Wulf et al., 1998). Others, however, noted that practice variables enhancing simple skills acquisition did not seem to be efficient for complex skills gain (Wulf et al., 1999). Also, it has been suggested that observational learning is sometimes sufficient to allow the development of an error detection mechanism necessary for improving performance (Blandin and Proteau, 2000). In our experiment, the subjects were taught to use FB (i.e., specific instructions) to gain control over their response patterns. The improved kinetic parameters in retention were not related to the provided FB except for the TRPF, which was the last discriminant factor entered in the LDA model. Nevertheless, the subjects reduced their TRPF (40%) and their TFPF (24%) in accordance with an increase in FPF, RPF, FFD, and RFD of 14%, 10%, 4%, 5%, respectively (Table IV). This reduction in the time to peak forces with the improvement in peak forces might have increased the rate of forces development, meaning that the shape of the force curves have changed from leptokurtic curves to positively skewed curves without affecting the TBT.

It has been suggested that the effectiveness of a FB training program should be measured not by the performance during training or at the end of a training session, but rather, by the performance in a no-feedback retention session in real-world settings that are the target of training (Salmoni et al., 1984).

Studies including a sport task were mainly conducted in laboratory settings raising questions about their external validity (i.e., transfer to training contexts) (Gauthier, 1985; Smith et al., 1997; Smith and Loschner, 2002; Viitasalo et al., 2001). Caution was made in Experiment 2 to provide FB in training context over several weeks when coaches were very attentive to technical aspects of the sprint start and to include a retention test one month after the last FB session. In spite of these efforts, the neutral effect of FB on starting block performance in our experiment may have been caused by the quality, quantity, and/or complexity of the provided FB. This statement is in agreement with Wulf et al. (1999), Wulf and Weigelt (1997), and Viitasalo et al. (2001) who reported that the effect of FB on a complex task might not be very effective. Compared to typical laboratory tasks, sport skills are generally more complex movements, involve the control of a greater number of degrees of freedom, require more practice to master, and take place in a specific context (Hebert et al., 1996). The starting block task was, perhaps, too complex motor a task to be modified in 6 weeks.

Finally, a simple linear regression analysis was computed to look at the strength training effect of force production on blocks. Since no significant relationship was revealed, it sounds rational to attribute peak force increases to the provided FB. Moreover, as displayed in Figure 2, the strength training density was reduced during FB sessions reinforcing the aforementioned result. Nevertheless, the subjects underwent plyometric training sessions during this phase, which had perhaps positively influenced the rate of force development.

CONCLUSIONS

In the first experiment, the LDA technique allowed identification of four kinetic parameters differentiating elite from sub-elite sprinters: (1) delay between end of rear and front force offset (DRF offset), (2) rear peak force (RPF), (3) total block time (TBT), and (4) time to rear peak force (TRPF). Experiment 2 examined whether providing FB on these variables to intermediate athletes could improve their starting block performance. Contrary to our hypothesis, FB did not help intermediate athletes to improve their starting block performance. A 6-week period is maybe too short to significantly modify performance on a complex motor task such as starting block.

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KEY POINTS

- The linear discriminative analysis allows the identification of starting block parameters differentiating elite from sub-elite athletes.
- 6-week of feedback does not alter starting block performance in training context.
- The present results failed to confirm previous studies since feedback did not improve targeted kinetic parameters of the complex motor task in real-world context.

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APPENDIX

As displayed in Figure 2, heavy resistance strength was developed during the physical preparation phase. The competitive phase was made up of starting block technique, speed skills and explosive strength while the subjects were maintaining acquired skills from the previous phase. Finally, the post phase was mainly used by athletes for restoration and/or maintenance of their basic skills. During this phase, no training on the starting block was done.

The equation to quantify the density (density defined as the total workload imposed to the athlete) was modified from Basset and Chouinard (2002). The overall strength-training units were taken into account to obtain a weight training density as follows:

$$D = \sum_{i=1}^n (I \times V \times \kappa) - r$$

where D is the density, I is the relative intensity, V is the volume expressed in number of repetitions, k is a constant, and r is the rest period in minute. In this equation n depends on the number of different intensities realized during the training unit. The

constant k corresponds to alactic anaerobic power (1), alactic anaerobic capacity (0.75), lactic anaerobic power (0.50) and lactic anaerobic capacity (0.25). These constants reflect the amount of energy needed to match a specific metabolic demand during exercise.

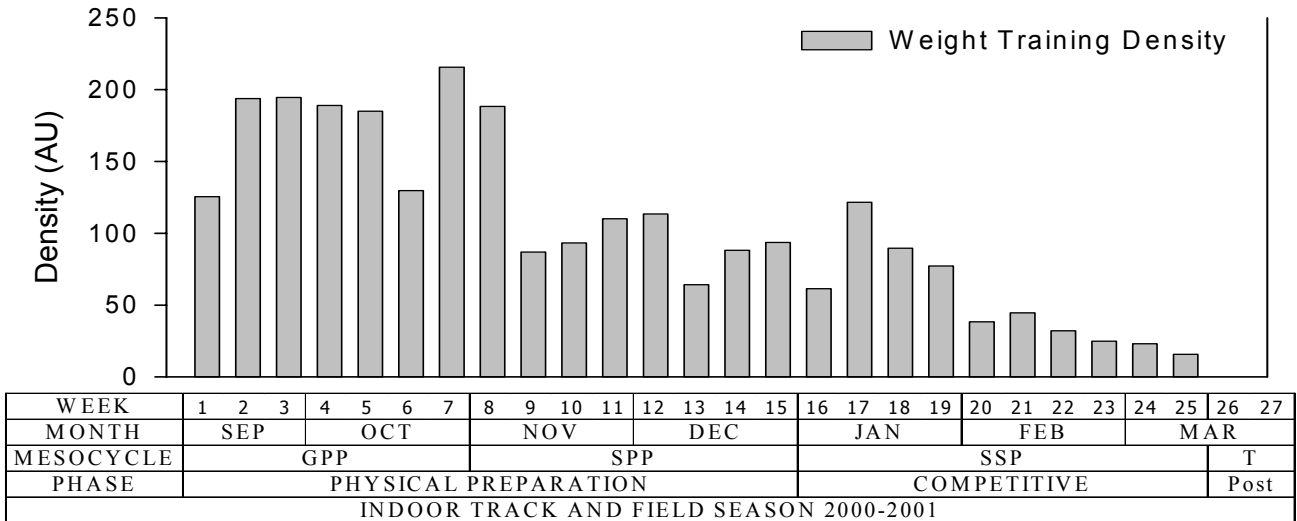


Figure 2. Strength density during indoor track and field season 2000-2001.