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Controlling locomotion during the acceleration phase in sprinting and long jumping

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The production of a stabilized locomotor pattern is crucial in sporting activities such as the run-up in long jumping, a task which is characterized by high spatio-temporal constraints. The aims of this study were as follows. First, we wished to investigate how athletes stabilize their stride patterns so as to strike the take-off board accurately. Previous studies have argued that during the initial accelerative phase of the run-up, athletes attempt to produce a stereotyped stride pattern. We investigated this initial phase in more detail by examining the kinematic parameters of long jumpers' strides and their spatial consequences. These data were then compared with the stride patterns observed in a sprinting task, which did not impose the same spatio-temporal constraints. Our second aim was to compare the stride patterns of skilled and unskilled jumpers.

Kinematic stride parameters were measured in two ways. The temporal parameters (flight time, stance time) were recorded by a microcomputer attached to the athlete, whereas the spatial parameters (stride length) were measured directly from the footprints the subjects made on the track. The results confirmed those of previous studies, showing that long jumpers initiate locomotor adjustments in the last 3–4 strides before take-off, but a more detailed analysis revealed that long jumping is characterized by adjustments during the first few strides. These adjustments were not seen in the sprinting task, where systematic variations of accumulated error were observed. These stride adjustments differed from those seen in previous studies and thus permit a more comprehensive understanding of the control involved in the tasks studied. The patterns exhibited by the skilled and unskilled subjects were very similar overall, but differed in that variations in accumulated error were less marked for the skilled subjects, who tended to make early stride adjustments sooner than the unskilled subjects. These results are discussed in relation to the cognitive and ecological approaches to movement coordination.

Keywords: Acceleration phase, control of locomotion, expertise, long jumping, sprinting.

Introduction

Many studies of motor activity have focused on locomotion, and the main characteristics of the repetitive locomotor programme have been described using neurophysiological (e.g. Grillner *et al.*, 1979) and biomechanical (see review by Rozendal, 1984) approaches. While being flexible, adaptable and modulable, it is also known to be a stable and reproducible programme. It was only recently that researchers began to investigate the control of locomotor activities involving severe spatio-temporal constraints (Lee *et al.*, 1982; Hay, 1988).

The concern of the present study, in line with those mentioned above, was how gait is regulated to fit the requirements of the terrain. We analysed the kinematics of the stride in two events, the run-up in long jumping and the acceleration phase in sprinting, so as to understand better how athletes produce a stable stride pattern. Moreover, in comparing the variations of the gait parameters in unskilled and skilled subjects, we focused on the systematic changes associated with increasing skill level. Of those studies concerned with the visual control of gait, only a few have dealt with the problem encountered by long jumpers. This can be summarized by saying that both the accuracy of foot positioning on the board and the speed of the jumper are of crucial importance in achieving a good performance. Lee *et al.*

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(1982) showed that there are two phases in the run-up: (1) an acceleration phase, during which the athlete produces a stereotyped stride pattern maintaining a constant impulse, thereby keeping the flight and swing-through times constant; and (2) a zeroing-in phase (the last three strides before take-off), during which the athlete adjusts his or her stride pattern to eliminate the spatial errors that have accrued during the first phase of the run-up. A crucial finding in this study was that stride length could be adjusted by modulating a single kinetic parameter of gait, namely vertical impulse. In addition, the time-to-contact to the board seems to be a valuable source of information for long jumpers, who can pick this information up via the optic variable *tau* and consequently modulate vertical impulse. Whatever the visual information used by long jumpers (see Warren *et al.*, 1986) and the gait parameters under their control (see Patla *et al.*, 1989), visual adjustments of the strides begin to occur in the last part of the run-up and these adjustments are initiated at various distances (and stride numbers) from the board. Hay (1988), for example, showed that on average, top-level jumpers make use of a visual control strategy from the fifth last stride onwards. Laurent and Pailhous (1982) pointed out that differences in skill level give rise to different patterns of stride adjustment before the take-off. Skilled jumpers anticipate their stride adjustments earlier than unskilled jumpers, who adjust their gait mainly during the last three strides. This result was also obtained in a visuo-locomotor positioning task, in which subjects walked towards a target placed on the ground (Laurent and Thomson, 1988).

Whatever the task, these last minute adjustments are necessary whenever precise foot positioning is required. In long jumping, they are necessary because the athletes cannot reproduce identical stride patterns (their practised stride pattern) from the starting mark to the board. Even a small error of just 1 or 2 cm per stride will add up during 20 or so strides, thus making a perfectly pre-planned run-up impossible. Since most previous studies on long jumping focused on the stride adjustments occurring just before take-off, the aim of the present study was to analyse more closely the initial part of the run-up. Very few data are available on the acceleration phase and its control, yet this phase is crucial in that it results in the error that the athlete must correct over the final few strides. This has important implications for training: the training method used depends upon what athletes really do during the action and how they control their action in the initial phase. The term ‘stereotyped stride pattern’, proposed by Lee *et al.* (1982), is not entirely satisfactory. Even if jumpers do indeed attempt to produce a constant impulse in the course of the acceleration phase, this does not preclude the use of a stride regulation strategy during this stage of the run-up. The duration of the acceleration phase (several seconds) leads us to hypothesize that athletes do adjust their strides. Thus, a detailed analysis of the build-up of accumulated errors should reveal differences between the long jump and the sprint because, in the latter task, athletes do not attempt to produce a regular locomotor pattern but try to achieve maximum speed.

We therefore examined the kinematic parameters of long jumpers’ strides and their spatial consequences (the accumulated error) in two different tasks: (1) the acceleration phase of long jumping and (2) sprinting. In the first of these two events, athletes have to aim at achieving both speed and stride length stability, whereas in the second, speed is the only constraint. In addition, we compared the stride patterns produced by unskilled and skilled subjects to assess whether skill is an important factor in accomplishing the task. For instance, do unskilled jumpers keep their flight time as constant during the initial part of the run-up as skilled jumpers do?

Methods

Subjects

The subjects were all students in the Faculty of Sport Sciences at the University of the Mediterranean and were aged 19–22 years. All the subjects volunteered to participate and were unaware of the aims of the study. Two groups were defined: five students who had had no special training in long jumping, and five skilled long jumpers with at least 5 years experience of jumping at a rate of three or more training sessions per week. The unskilled group’s mean (– S.D.) long jump performance was 5.62 –0.31 m, whereas that of the skilled jumpers was 6.75 –0.23 m. These figures were based on the mean scores obtained by the unskilled subjects in athletics as part of their curriculum at the university, and on those obtained during one season in the case of the skilled long jumpers.

Tasks

Each subject had to perform two tasks. In the first, a sprinting task, the subjects had to run as fast as possible to a point 35 m away. The first 14 strides were analysed, just as in the long jumping task. In the long jumping task, the subjects had to jump after a run-up consisting of 14 strides. In this latter task, the subjects were asked to produce the longest possible jump while obeying the rules; that is, they were not allowed to overstep the edge of the board. A fixed number of strides was imposed with a view to comparing the unskilled and skilled subjects' performances. We chose 14 strides because this is the number of strides unskilled subjects normally take during the run-up. The use of a 14 stride run-up did not present the skilled subjects with a novel task. Though shorter than that used normally in outdoor competition (18–20 strides), such run-ups are regularly used in training sessions and indoor competition.

Procedure

In a preliminary session, all the subjects practised the 14 stride run-up. The experiment itself consisted of two separate sessions. During the first session, the subjects undertook six trials of the sprinting task. A break of on average 8.5 min was allowed between trials to allow the subjects to recover. During the second session, the subjects undertook six trials of the long jumping task. The starting point was the same in all trials and no checkmarks were used on the track. Checkmarks were not permitted because their role in the run-up is not clear and because they are not used by unskilled subjects. Their use would therefore have made it impossible to compare the two groups in terms of their visual guidance to the take-off board. The subjects adopted exactly the same position at the start of both tasks, a standing start with their push-off leg on the starting line, and they were asked to make no changes in their starting position from one trial to another. In the two tasks, no starting orders were given, the subjects starting when they felt ready to do so.

Data recording

The length of each stride was measured after each trial from the footprints left by the subjects' cleated running shoes on the cinder track. A hectometre rule placed along the track was used to measure the cumulated stride distances from the starting point. These data yielded all the spatial parameters investigated. The use of footprint measurements is a rather laborious method, but is accurate to within –1 cm per stride. After each trial, the track was rolled smooth so that no errors could be made when measuring footprints on subsequent trials.

The temporal data were recorded with a portable microprocessor worn on the subject's back and connected to switches set in a pair of removable soles in the subject's shoes. This device was developed at the CNRS Institute of Neurophysiology and Psychophysiology in Marseille (see Zenatti, 1985). The system was driven by a computer comprising a processor, timing function (a 16 bit programmable timer used with a time base of 4.9152 MHz), memory and various interfaces that recognized and recorded the time of events (the landing and take-off of the feet). The start of an event was defined as the moment at which any part of the foot touched the ground, and was identified by pressure switches placed on the front and heel of the foot. The data recorded by the portable computer were subsequently transferred via a standard RS232 link to a larger computer for final storage and analysis. The precision of the measures was limited by that of the analog-to-digital converters (8 bits), which was 0.3%. The accuracy of the results, estimated on the basis of laboratory tests, was of the order of –1 ms.

Dependent variables

The variables studied were defined as follows:

- *Stride length*: the distance between two consecutive footprints from the tip of one foot to that of the other.
- *Stance duration*: duration of foot contact with the ground.
- *Flight duration*: time spent not in contact with the ground.
- *Accumulated spatial error*: the standard deviation of the mean toe–starting point distance across trials.
- *Target positioning error*: the distance from the toe of the subject's foot to the front edge of the take-off board.

Results

Overall results

Table 1 presents the absolute values of the mean velocities, the mean stride durations and lengths recorded in the unskilled and skilled subjects during the two tasks.

Sprinting task

The unskilled subjects covered a mean (– S.D.) distance of 21.46 –0.29 m in their 14 strides in a time of 3.60 –0.31 s; that is, their mean velocity was 5.96 $m\ s^{-1}$. The skilled subjects covered a mean distance of 23.84 –0.80 m in 3.40 –0.08 s, a mean velocity of 7.01 $m\ s^{-1}$.

Long jumping task

The mean length of the unskilled subjects' run up was 22.10 –1.21 m, covered in a time of 4.13 –0.29 s; that is, a mean velocity of 5.38 $m\ s^{-1}$. The skilled subjects covered 25.41 –1.29 m in 3.79 –0.19 s, a mean velocity of 6.70 $m\ s^{-1}$. The mean targeting position

Table 1 Stride lengths, durations and velocities in the sprinting and long jumping tasks for the skilled and unskilled athletes (mean – S.D.)

	Unskilled			Skilled		
Task	Stride length (m)	Stride duration (s)	Speed ($m\ s^{-1}$)	Stride length (m)	Stride duration (s)	Speed ($m\ s^{-1}$)
Sprinting	1.53 –0.25	0.26 –0.5	5.96 –0.31	1.66 –0.29	0.24 –0.02	7.01 –0.29
Long jumping	1.58 –0.26	0.29 –0.06	5.38 –0.40	1.82 –0.31	0.27 –0.04	6.70 –0.30

error of the unskilled subjects (0.21 –0.12 m) was significantly greater than that of the skilled subjects (0.10 –0.05 m) ($t = 3.08$, $P < 0.05$).

Analysis of the variables

A separate analysis of variance was undertaken for each of the variables investigated (stride length, stance time, flight time and accumulated spatial error). The analyses used group (skilled *vs* unskilled) as a between-subjects factor and task (sprinting *vs* long jumping) and stride rank as within-subjects factors. The stride rank represented the number of the stride in the sequence; that is, stride rank 14 represented the last stride before the jump. To reduce the risk of Type I error owing to the use of separate analyses of variance for each dependent variable, a somewhat conservative procedure was adopted by evaluating each comparison at the 0.01 level.

Stride length

The results of the analysis of variance on stride length showed that the effects of task ($F_{1,8} = 28.89$, $P < 0.001$) and rank ($F_{13,104} = 197.63$, $P < 0.001$) were significant, as was the group × rank interaction ($F_{13,104} = 7.14$, $P < 0.001$). The effect of group ($F_{1,8} = 7.42$) and the group × task ($F_{1,8} = 7.3$) and task × rank ($F_{13,104} = 3.21$) interactions were not significant. These results show that both the unskilled and skilled subjects took longer strides in the long jumping compared with the sprinting task.

Stance time and flight time

The factor rank ($F_{13,104} = 24.82$, $P < 0.001$) and the interaction between task and rank ($F_{3,104} = 5.05$, $P < 0.001$) were found to have had significant effects on stance duration. Although no significant differences were observed between the skilled and unskilled subjects' stance durations, they were to decrease as velocity increased. The factor task ($F_{1,8} = 103.26$, $P < 0.001$) and the group × task ($F_{1,8} = 11.35$, $P < 0.001$), group × rank ($F_{13,104} = 3.77$, $P < 0.001$), task × rank ($F_{13,104} = 4.47$, $P < 0.001$) and group × task × rank ($F_{13,104} = 3.21$, $P < 0.05$) interactions were found to have significantly affected flight times in both groups. Flight time was longer in the long jumping than in the sprinting task: 151 and 158 ms for the sprinting task and 186 and 175 ms in the long jumping task for the unskilled and skilled subjects, respectively. A supplementary analysis of the long jumping data showed that rank ($F_{13,104} = 3.23$, $P < 0.001$) and the group × rank interaction ($F_{13,104} = 9.35$, $P < 0.001$) had significant effects on flight time. This was because rank significantly affected flight time in the unskilled subjects only. Flight duration was consistent among the skilled subjects, whereas it was variable among the unskilled subjects, decreasing gradually during the run-up. Similar analyses were performed on the sprinting data but no significant differences were found between the two groups, whose stride patterns were very similar in this task.

Accumulated spatial error

Figure 1 charts the build-up of accumulated spatial error during the 14 stride run-up. The results of the analysis of variance showed that rank ($F_{13,104} = 47.31$, $P < 0.001$) and the task × rank interaction ($F_{13,104} = 10.23$, $P < 0.001$) were significant. Neither group ($F_{1,8} = 5.44$) nor task ($F_{1,8} = -4.99$) had any significant effect. The accumulated spatial error was seen to evolve differently in the two tasks. Regression analysis showed that the accumulated spatial error fitted a linear function in the sprinting task for both the unskilled ($R^2 = 0.99$, $P < 0.0001$) and skilled ($R^2 = 0.99$, $P < 0.0001$) subjects. The results of a second-degree polynomial regression carried out on the same factors did not give rise to higher coefficients of determination. On the other hand, regression analysis performed on the long jumping data revealed that the accumulated spatial error fitted a quadratic function better in the case of both the unskilled ($R^2 = 0.99$, $P < 0.0001$) and skilled ($R^2 = 0.98$, $P < 0.0001$) subjects than for a linear function ($R^2 = 0.56$, $P < 0.001$ and $R^2 = 0.32$, $P < 0.05$ for the unskilled and skilled subjects, respectively). The results of the regression analyses clearly demonstrate that the accumulated spatial error increased gradually stride by stride in the sprinting task, whereas it decreased at stride 11 for the unskilled subjects and at stride 10 for the skilled subjects in the long jumping task. With reference to the take-off board, the results indicate that the subjects adopted a visual control strategy on the eleventh stride in the case of the unskilled subjects and on the tenth stride in the skilled subjects.

The present results, obtained with a 14 stride run-up, are comparable to those found with a full-length run-up of 18–20 strides. Hay (1988), for example, noted a reduction in cumulative error in expert subjects starting at a mean distance of five strides from the take-off board. More recently, Berg *et al.* (1994) reported similar results.

All of the subjects began to adjust their stride length in relation to the take-off board after the tenth stride. Both the unskilled and skilled subjects exhibited a larger accumulated spatial error in the long jumping compared with the sprinting task. This was unexpected, since long jumping is known to be an activity in which competitors try to achieve the greatest possible stride stability from one jump to the next.

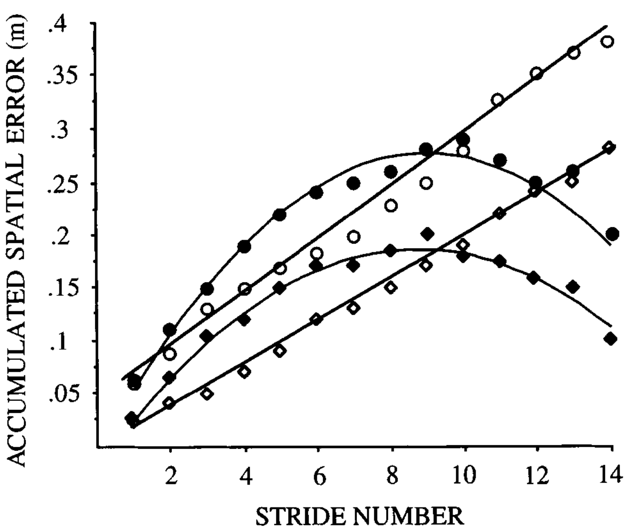

Figure 1 Accumulated spatial errors at each stride in the 14 stride sequence for the skilled and unskilled subjects during the sprinting and long jumping tasks. The shape of the curves differ between the two groups for both tasks. There was a gradual increase in accumulated spatial errors in the sprinting task, whereas they began to decrease form the tenth or eleventh stride in the skilled and unskilled subjects, respectively. There were also marked differences in the mean accumulated spatial error between the two groups. The errors of the unskilled subjects were larger than those of the skilled subjects in both tasks. ●, Unskilled long jumpers; ◆, skilled long jumpers; ○, unskilled sprinters; ◇, skilled sprinters.

Comparisons between individual and mean stride length: The 'index of variation'

With a view to carrying the analysis a stage further, we examined whether stride length during the initial acceleration phase was subject to some form of control. Assuming that the subjects may have tried to achieve a repetitive stride pattern, each subject's mean starting point–toe distance was taken as a reference stride pattern to which each stride in individual trials could be compared. This yielded an index of variation. When the starting point–toe distance recorded in one trial was identical to the mean pattern, it was impossible to tell whether or not an adjustment had been made. Trials were therefore selected on the basis of the following criterion: when the difference between one starting point–toe distance and the mean length of the reference pattern was greater than 20 cm, the trial was selected for analysis because this difference meant that adjustments would definitely be necessary in order to position the foot accurately on the take-off board. It was considered, in agreement with Hay (1988), that a cumulative error greater than 20 cm indicated a poor performance which demanded stride regulation. Figure 2 shows an example of the differences observed between the reference pattern and stride length for trials which were selected in a skilled subject performing both the long jumping and sprinting tasks. Negative values mean that stride length in a trial was shorter than the mean, and positive values that stride length was longer than the mean.

Using the above procedure, 60 trials were selected, 35 involving unskilled subjects and 25 involving skilled subjects. As shown in Fig. 3, the index of variation fitted a linear function in the sprinting task (R^2 = 0.98, P < 0.0001) and a quadratic function in the long jump task (R^2 = 0.97, P < 0.0001) in both groups. The index of variation in the sprinting task provided a baseline value, since the subjects did not attempt to produce a stable spatial pattern. In the long jumping task, early stride adjustments, both lengthening and shortening of strides, were found to occur in both groups of subjects six strides from the start. Such regulation could not have been visual adjustments related to the take-off board. This does not mean that vision was not used to control the subjects' actions, but merely that, at this distance from the board (15 m on average), the visual regulation of strides with reference to the take-off board described by Lee *et al.* (1982) could not have played a role. Berg *et al.* (1994) suggested that such adjustments never begin before the sixth stride (about 13 m). The present study, however, suggests that all the subjects made early adjustments in the long jumping task after the first six strides. On average, this occurred at a distance of 8.8 m from the starting point, 1.81 s after the starting time.

Discussion

After outlining the overall results obtained in the above experiment, we discuss the specific question as to how the initial part of the run-up is controlled in long jumping. First, however, a few comments are called for with regard to the subjects' levels of skill and the differences to which these gave rise in the two tasks. Level of skill was found to have significantly affected the main locomotor parameters, such as velocity, overall stride pattern and, in the case of the long jumping task, the accuracy of positioning the foot at take-off. The skilled subjects' locomotor patterns were more regular than those of the unskilled subjects, probably because they

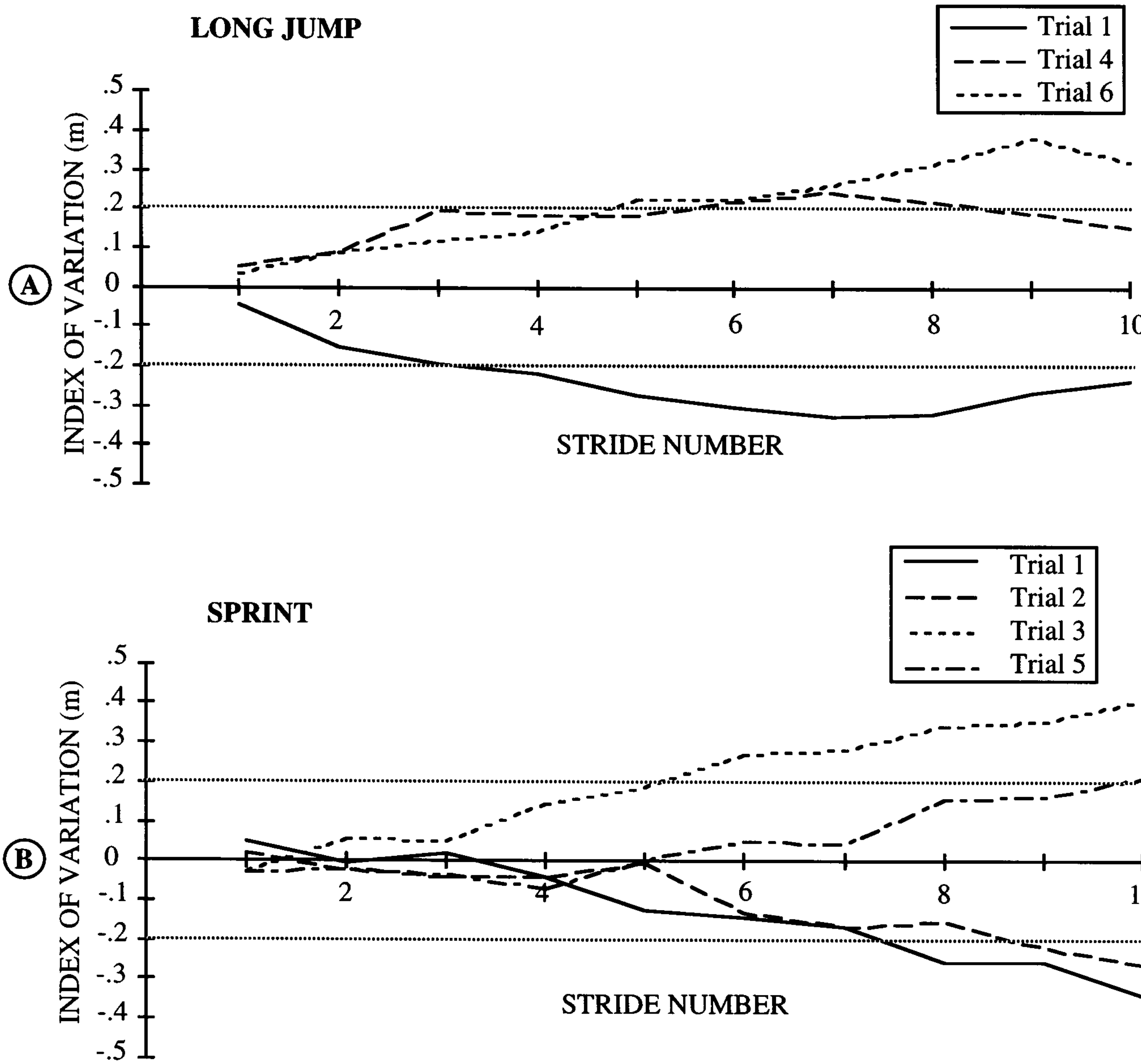

Figure 2 Differences between stride length in the individual trials and mean stride length (the index of variation) in (A) the long jumping task and (B) the sprinting task for a skilled subject. Positive values reflect that stride length was longer than the mean and negative values that it was shorter than the mean. These trials were selected from the six trials in each task based on the following criterion: the difference between the length of a given stride and the mean length of that stride over the six trials was greater than 0.2 m. This meant that adjustments were necessary for accurate positioning of the foot at the take-off board (see text).

had mastered the time components of the strides. The stance and flight durations were very asymmetrical between the right and left foot in the case of the unskilled subjects, which is consistent with the observations of Hay and Schoebel (1990) in relation to female hurdlers. Higher levels of skill led to a smoothing out of the athletes' performances. The overall spatio-temporal patterns and the accumulated error were found to differ significantly between the sprinting and long jumping task: the stride lengths were longer and the frequencies lower in the run-up than in sprinting. The

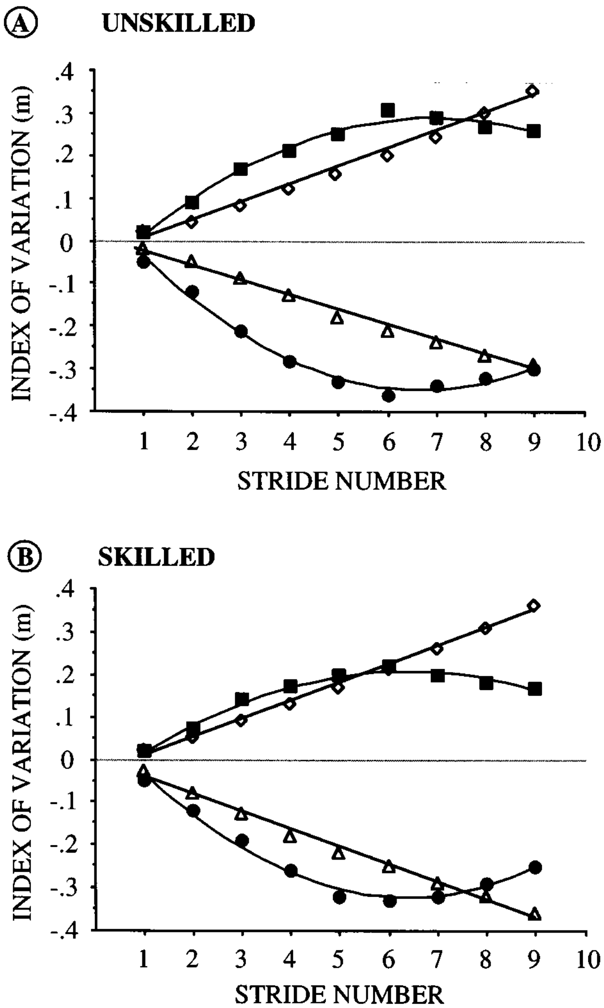

Figure 3 The mean index of variation (IV) for the two groups in the sprinting and long jumping tasks. The IV pattern can be seen to differ depending on the number of the stride in the sequence, regardless of whether the stride was longer (positive values) or shorter (negative values) than the mean. The early adjustments differed depending on the task. The skilled subjects also adjusted their stride patterns earlier than the unskilled subjects (see text). ●, Shortened stride, long jumping; ■, lengthened stride, long jumping; △, shortened stride, sprinting; ◇, lengthened stride, sprinting.

pattern typical of long jumping, with very rhythmic strides and a tendency to leap higher in the air and to strike the ground more strongly, was found to include a phase during which the flight times stabilized, which was particularly noticeable in the case of the skilled long jumpers. The results of the analysis of the subjects' accumulated spatial error during the first few strides was lower in sprinting than in long jumping, despite the fact that it is in the latter event that athletes usually try to stabilize their stride lengths. There are two possible explanations. First, the velocity may have accounted for the difference in accumulated spatial error between the two tasks. When the athletes approached the board, their mean velocity was lower (4% lower in the skilled and 12% lower in the unskilled subjects) than when they were sprinting. In sprinting, the optimum stride frequency:impulse ratio may have been reached, which stabilized the locomotor pattern, because the athletes were trying to thrust forward to reach maximal speed. The second explanation is that the locomotor pattern during the run-up was more flexible, since visual adjustments are still possible during the final approach phase, but this in turn generates variations in the initial part of the run-up.

Another point worth considering concerns the results obtained during the acceleration phase, which were contrary to what we assumed at the beginning of the study. The differences in accumulated spatial error patterns between the two tasks seem to suggest that the subjects' locomotion was controlled in a different fashion in the sprinting and long jumping tasks. We found that the mean accumulated spatial error was higher in the long jumping than in the sprinting task, despite the fact that long jumpers try to minimize the differences in their step-length patterns from one trial to another. In the trials in which the subjects adjusted their strides, they were found, on average, to do so six strides after the start in the long jumping task. These adjustments were different to those observed in previous studies, where the accumulated spatial error was found to decrease between three and four strides before take-off (Lee *et al.*, 1982; Hay, 1988; Berg *et al.*, 1994). These last minute adjustments are believed to be visually referred to the board. The evidence for stride adjustments in the initial phase does not call into question the existence of adjustments in the final phase. We believe that the two types of adjustment are complementary and that both are necessary for the performance of the task.

How can this much earlier decrease in the index of variation be accounted for? First, it should be noted that it did not occur in the sprinting task. From a comparison of the two tasks, one could argue that it was not simply an everyday effect of locomotion, but instead resulted from a deliberate attempt on the part of the subjects to control their stride patterns. This may have involved one of two processes. The first is a visual open loop control process, whereby a programme learned by training and repetition becomes integrated. Here the very stable flight periods observed among skilled subjects in the long jumping task might serve as a kind of 'internal clock', which is used by athletes to time their movements. Learning to perform long jumping would therefore involve the integration of this rhythmic pattern. The run-up might consist here of delivering a series of maximal forward thrusts at regular intervals. Controlling the acceleration phase might involve making comparisons between the actual proprioceptive sensory effects of the subjects' movements with the expected consequences – that is, those predicted by the motor programme (in the same sense as used by Schmidt, 1988). The stride adjustments found to occur during the initial phase are consistent with a process of this kind. Acquiring this particular motor skill may consist of reinforcing the parametric motor plan. The data show that an error correction process tends to operate after the first six strides in the run-up sequence. During the initial part of the run-up, long jumpers may not just produce a stereotyped pattern as suggested by Lee *et al.* (1982), but may make specific adjustments to their locomotor pattern. Thus, within the framework of a cognitive conception of motor control, one is led to interpret the results as demonstrating that the control of the action – which is characterized by a reduction in the cumulative error or index of variation – is based upon a comparison between the current visual and proprioceptive consequences of locomotion and the same sensory information stored in memory during the course of training.

The second process involves the visual control of the acceleration phase. Long jumpers may attempt to stabilize one of the spatio-temporal components of optic flow. In this way, any deviations from the reference value would be detected and corrected at each stride. We are therefore concerned here with continuous control of the type that Bootsma and Van Wieringen (1990) suggested operates in striking a table tennis ball. The stride length adjustments observed may therefore result from a change in the forward drive, which itself may depend on the optic flow (e.g. Warren *et al.*, 1986). Within this approach, the stability of stride length is only a consequence of a constant and near maximal impulse. The inertia that has to be overcome, owing to the standing start, accounts for the progressive acceleration of the athlete. It is relevant to raise here the idea of a law of control, such as that proposed by Warren *et al.* (1986), of the form $I = mg\,\Delta\,\tau$ (where I = vertical impulse, m = the mass of the subject, g = the gravitational acceleration and τ = the optical variable tau) for the regulation of the adjustments to the take-off board. Such an explanation is very persuasive, as it requires no recourse to stored information or motor programmes, thus simplifying the control that must be effected. It should be noted, however, that the same law of control could not underlie both the long jump and the sprint, as the subjects' objectives in the two tasks are not identical. It is not possible on the basis of the present results to determine which (if either) of these potential mechanisms mediates stride control during the early stages of the run-up. Further research to identify a plausible law of control of the stride, possibly involving the restriction of visual information, is necessary. It is worth noting that the present study revealed the occurrence of early adjustments in long jumpers' stride patterns, which were not the same as those observed in sprinting during the acceleration phase or those made by long jumpers at a later stage, as they approached the take-off board, which were definitely under visual control.

The practical consequences of the results for the training of long jumpers are two-fold. First, the fact that adjustments are seen during the initial phase of the approach supports the notion that long jumpers cannot produce a completely constant stride pattern (as work on the visual guidance of the approach to the take-off board has already shown). Training should not thus be solely concerned with the search for perfect regularity, but should emphasize continuous stride control. For example, one possibility could be the systematic modification, without the knowledge of the athlete as to its nature and extent, of the position of the starting mark by several centimetres in the course of training. The run-up would, in this case, become a task which more explicitly required continuous control to deal with the environmental constraints. Secondly, the comparison between the sprint and long jump run-up demonstrates that they are two different tasks, not only in terms of their goals, but also in their locomotor kinematics. As a result, performance of the run-up without the final jump is of little pedagogic value, even for the initial phase of the approach.

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