STRIDE PATTERN CHARACTERISTICS AND REGULATION OF GAIT IN THE APPROACH PHASE OF THE LONG JUMP IN VISUALLY IMPAIRED ATHLETES

Theodorou[1], A., Skordilis[1], E., Padulles[2], JM., Torralba[3], MA., Tasoulas[4], E., Panteli[1], F and Smirniotou[1], A.

[1]Kapodistrian University of Athens

[2]Institut Nacional d'Educació Física de Catalunya

[3]Universidad de Barcelona

[4] International Paralympic Committee

Research has shown that long jumpers visually regulate their stride pattern as they approach the take-off board demonstrating an ascending-descending trend of variability rather than a consistent pattern of foot placement over trials. The present study examined whether visually impaired (VI) long jumpers show a similar pattern of variability in footfall placement between trials as their non-VI counterparts. The four finalists of the men's long jump (category B1; no light perception in either eye), of the IBSA 2009 European Athletics Championship were recorded using a panned video camera. Results showed that VI long jumpers demonstrated an initial ascending variability proceeded by a descending order near the take-off board suggesting some type of regulation. This control emerged on the fourth (mean 3.67±0.58) support phase (i.e. third stride) prior to take-off and at a mean distance of 6.26 m (±0.60m) from the take-off board when TBD variability reached a maximum value of 0.40 m (±0.09m). Last stride TBD variability was 0.25 m (±0.10m). Mean step length for the final strides (from last to 4th) was 198, 232, 207 and 219 cm respectively.The striding pattern observed was similar to that reported in the literature for non-VI athletes (Hay and Koh 1988, Berg and Greer 1995). The max TBD variability was comparable to that of non-VI athletes while step length met the criteria of the appropriate approach run technique. However, the regulation commenced a stride later (stride 3 instead of 4 from the board) while last stride TBD variability was slightly larger possibly due to the larger size of the board (1 x 1.25m) used in VI athletes (category B1). These data extend our current understanding of the regulation of goal-directed gait. However, further research is required to determine the origin and source of the regulation (audial or perceptual).

1. Introduction

The long jump is an athletic event separated into four distinct segments: a speedy approach phase, an explosive take-off, a flight phase through the air and a landing in a sandpit (Hay, 1986). A successful jump has been shown to be heavily dependent on the performance of the approach phase. The long jumper during the approach run has three primary tasks to perform: (a) to develop a maximal manageable horizontal velocity that can be used effectively during the takeoff; (b) to adjust the position of the body during the final few steps to bring it in an optimal take-off position with minimum loss of horizontal speed and (c) to precisely adjust step length so that foot placement at jump takeoff is as close as possible to the distal edge of the 20-cm board from which the jump is measured (Hay, 1988; Hay & Koh 1988). The task of striking the take-off board with precision, speed and appropriate technique is a major task constraint on the performer. To optimize accuracy, long jumpers are commonly instructed to develop an approach consisting of a stereotyped gait pattern, that is, one in which there is little variation in foot placement across trials. Rehearsal of this skill typically involves the performance of numerous repetitions of a particular gait pattern during training. Theoretically this type of practice is in accordance with the traditional views of developing a motor programme for a reliable and consistent gait pattern for use in changing performance conditions (Schmidt and Lee 2005). Additionally, for many years, athletics coaching manuals emphasized the importance of maintaining a consistent striding pattern to the board and admonished readers that they should, under no circumstances, adjust this pattern to ensure that the takeoff foot strikes the board (Hay 1988).

Lee et al. (1982) reported that it was not feasible for long jumpers to rely completely on a consistent step pattern to bring them precisely to the front edge of the takeoff board at the end of the approach. They argued that the approach phase of the long jump actually consisted of two sub-phases: an accelerative phase and a zeroing-in phase. It was proposed that skilled athletes maintained a constant stride pattern while progressively increasing their stride lengths as they accelerated down the track. However, small inconsistencies in stride length had an unavoidable, cumulative effect which resulted in the build-up of footfall variability until the fifth-from-last step. Unavoidably, it was necessary for jumpers to modify step length near the end of the approach to compensate for any previous deviation from their standardized step pattern. The zeroing-in phase was considered to start after the highest value of the standard deviation of the footfall placement was recorded, when the variability switched from an ascending trend to a descending trend. The study of Lee et al. (1982) paved the way for numerous studies to follow on that topic. Subsequent studies of expert, novice and even non-long jumpers revealed that step length adjustment toward the end of the approach run for the purpose of enhancing takeoff accuracy is a ubiquitous feature of task performance (Berg & Mark 2005; Berg, Wade & Greer, 1994; Bradshow 2005; Hay, 1988; Hay & Koh 1988; Scott, Li & Davids, 1997).

Long jump is one of the recognised events in the International Blind Sport Association (IBSA) and Paralympics competition programme and among the ones that attract a large number of high level competitors. The relationship between visual function and performance in sports is thoughtlessly obvious. Long Jump competitors in the B1 category have no light perception in either eye or up to light perception but inability to recognize the shape of a hand at any distance or in any direction. In this category the Long Jump take-off area consists of a rectangle (made by the use of powder, or light sand, etc.) 1 x 1.22 metres, that the athlete leaves an impression on the area with his or her take-off foot. All the other relevant IAAF Rules for the horizontal jump are applied. Until recently there has been a lack of qualitative and quantitative analysis of track and field athletes with disabilities. This suggests that there is a definite need to expand research into the area of movement analysis of visually impaired (VI) athletes and try to establish the spatio-temporal skills that they posses and which would help their non-VI counterparts. Based on the above, the purpose of the present study was to record the stride characteristics and examine whether visually impaired long jumpers whose training and performance is based exclusively on repeating and producing stereotyped gait patterns demonstrate a similar pattern of variability in footfall placement between trials as the non-VI athletes.

2. METHODOLOGY

2.1. Participants

At the study participated the four finalists of the men's long jump (category B1; no light perception in either eye), of the International Blind Sport Association (IBSA) 2009 European Athletics Championship. Testing took place at the athletics stadium during the men's final of the long jump event.

2.2. Data collection

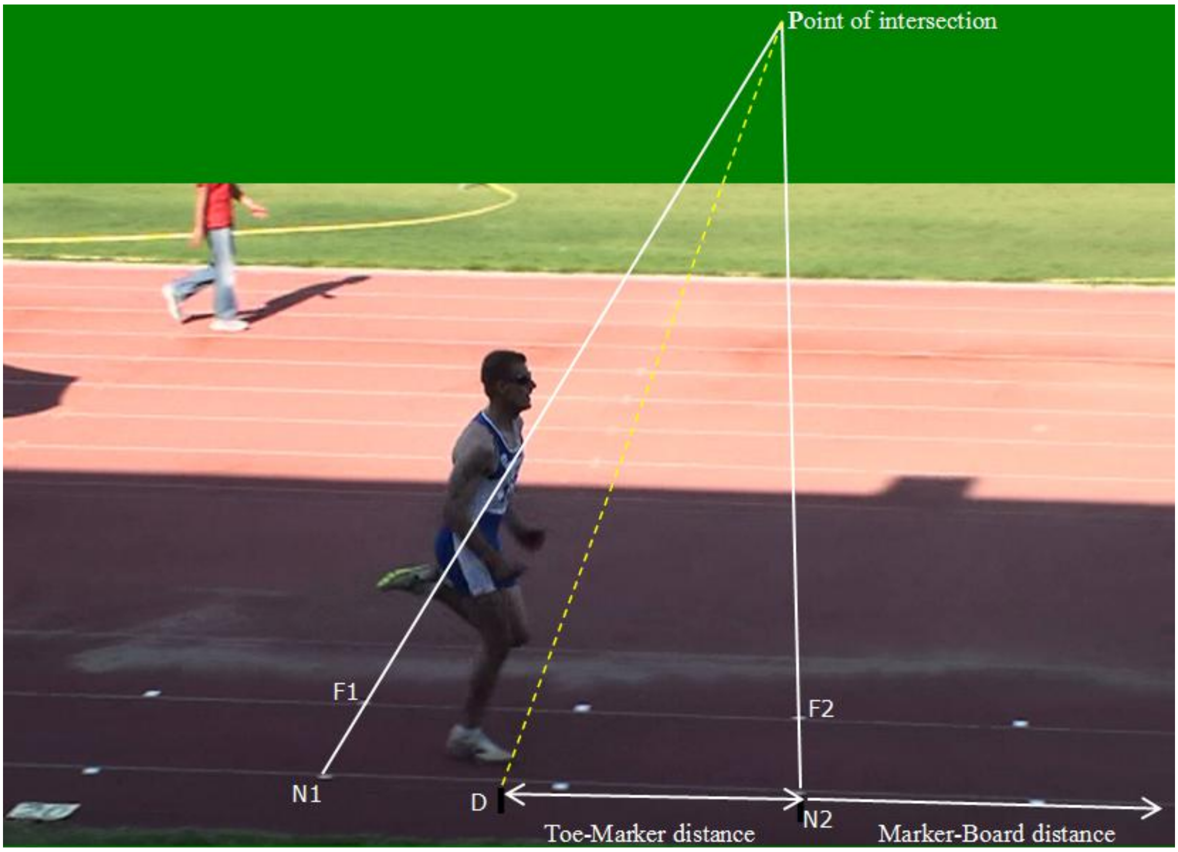
Forty (40) 1.0-m zones were established on the runway and were designated by white markers placed at 1m intervals on either side of the runway and parallel to its long axis. This was to enable calculation of the horizontal distance between the toe and take-off board (toe-board distance). The approach phase of each long jump was recorded using a digital video camera (SONY HDR-SR10) operating at 50 frames per second. The camera was manually panned to allow the whole of each subject's run-up to be recorded. The panned camera was positioned at a distance of 15 m from the midline of the runway and elevated at a height of 5 m so that the markers on both sides of the runway were visible. In total, 22 run-ups were analysed, yielding a minimum of 5 jumps per individual subject.

2.3. Data reduction

TBD was calculated according to the method described by Hay and Koh (1988). This procedure required initially the designation of the toe-marker distance. The toe-marker distance was determined by projecting the position of the toe onto a line between the two near markers that had been digitized. The standard deviation (SD) of TBD for each step across trials for each subject was taken as a measure of variability of foot placement for a particular step. The SD of TBD recorded for each support phase was computed for each subject. These values were then plotted against the number of the support phase, as shown in the example of Illustration 1. The onset of stride regulation was identified as the point at which the maximum SD in TBD occurred, provided the variability associated with subsequent footfall positions decreased systematically thereafter (Lee et al., 1982; Hay and Koh, 1988; Berg, Wade & Greer, 1994). Step length was determined by the subtraction of toe-board distances. Stride frequency and stride speed were calculated as follows:

- Stride frequency = no of stride/time
- Stride speed = stride length / stride time

Illustration 1. An example of how toe-marker distance and toe-board distance was measured



3. Results

Table 1. Performance and approach run characteristics of the long jump finalists competing at the category B1 of the IBSA 2009 Athletics European Championship.

Athlete	Place	No of Jumps	Best Jump (m)	Mean performance (m±SD)	No of strides	Run-up length (m±SD)	Stride length (cm±SD)	Stride Frequency (HZ±SD)	Speed $m.sec^{-1}$
Mparakas	1	6	5.97	5.81 ±0.10	16	35,27 ±0.26	216.25 ±26.5	3.28 ±0.10	7.22 ±0.81
Porras	2	6	5.90	5.74 ±0.17	16	33,50 ±0.32	208.22 ±16.7	2.72 ±0.26	5.71 ±0.49
Koptev	3	5	5.71	5.56 ±0.13	16	31.52 ±0,11	194.56 ±23.2	3.29 ±0.16	6.56 ±0.58
Hendry	4	5	5.45	5.26 ±0.18	16	29.89 ±0,7	182.92 ±24.1	3.47 ±0.11	6.50 ±0.73

Table 2. Stride length, stride frequency and SD of TBD of the last 10 strides of the approach run.

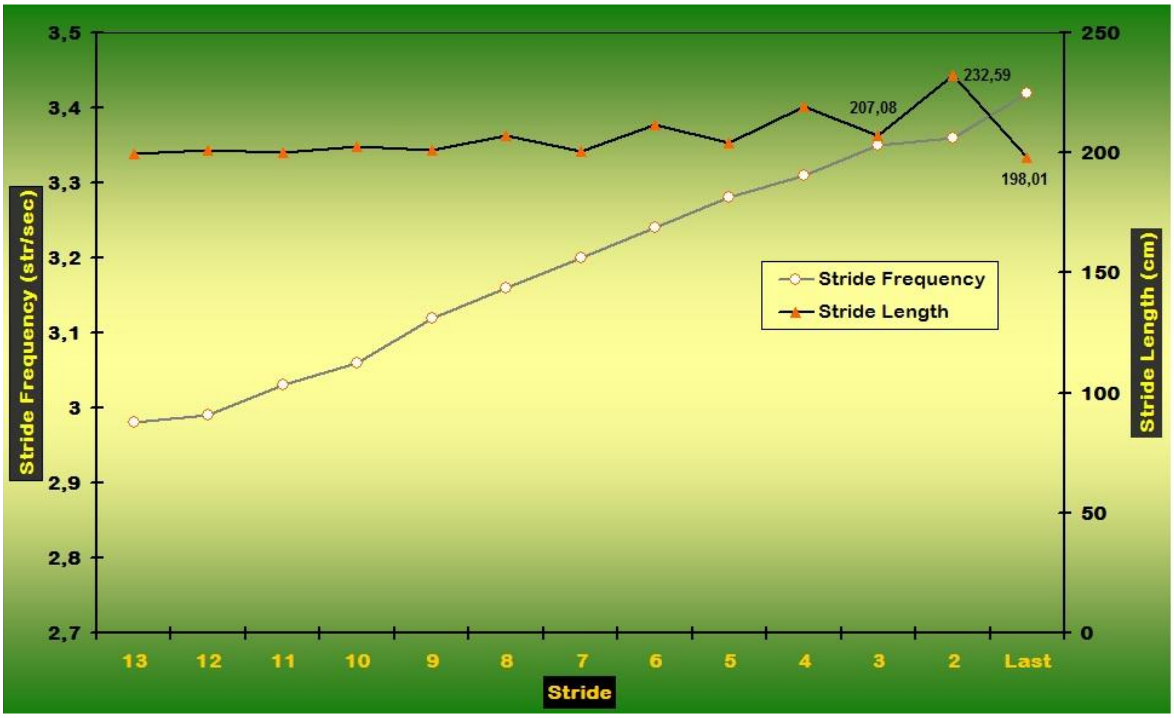
Athlete		Last	2^{nd}	3^{rd}	4^{th}	5th	6th	7th	8th	9th	10th
Mparakas	**Length (cm)**	207	274	225	245	220	236	219	230	217	224
	Frequency (str/sec)	3.42	3.36	3.38	3.33	3.32	3.30	3.28	3.26	3.22	3.18
	SD of TBD	36.41	38.17	46.40	37.32	34.36	32.93	29.22	28.57	22.96	25.75
Porras	**Length (cm)**	223	209	194	202	193	196	199	199	203	202
	Frequency ((str/sec)	3.14	3.08	3.04	2.97	2.91	2.85	2.77	2.70	2.62	2.55
	SD of TBD	28.43	26.57	24.17	21.81	20.54	16.83	16.55	11.79	11.39	10.89
Koptev	**Length (cm)**	173	221	211	216	200	213	194	204	202	200
	Frequency ((str/sec)	3.54	3.47	3.44	3.42	3.37	3.34	3.29	3.24	3.20	3.15
	SD of TBD	16.53	25.74	41.59	45.31	45.30	42.54	43.64	45.63	43.80	36.95
Hendry	**Length (cm)**	186	224	196	211	201	200	190	193	181	182
	Frequency ((str/sec)	3.60	3.54	3.55	3.52	3.52	3.49	3.47	3.44	3.41	3.37
	SD of TBD	23.73	20.78	22.62	29.18	28.45	23.71	21.57	23.24	21.00	18.71
Mean	**Length (cm)**	**198**	**232**	**207**	**219**	**203**	**211**	**200**	**207**	**201**	**202**
	Frequency ((str/sec)	**3.42**	**3.36**	**3.35**	**3.31**	**3.28**	**3.24**	**3.20**	**3.16**	**3.12**	**3.06**
	SD of TBD	**25.56**	**28.23**	**36.87**	**37.27**	**36.04**	**33.06**	**31.48**	**32.48**	**29.25**	**27.14**

4. Discussion

4.1. Stride pattern characteristics

The approach run of all finalists ranged from 29 to 35 meters and was comprised by 16 strides. All the athletes initiated their run from a standing position progressively increasing their speed as they accelerated down the runway. Among the finalists, average stride length ranged from 182 to 216 cm. The striding pattern observed was similar to that reported in the literature for non-VI athletes (Hay and Koh 1988, Berg and Greer 1995). As shown on Table 2 and Figure 1, as the athletes accelerated down the runway stride length was progressively increased while the last three strides prior to take-off fulfilled the technical requirements of the event (i.e. 3rd to last: average stride; 2nd to last: large stride; last: small stride). Additionally, stride length was found to be significantly correlated ($r = 0.537$, $p < 0.05$) with average stride frequency which, among athletes, ranged from 2.72 to 3.37 str/sec and progressively increased as the athletes approached the take-off board. Average approach run speed, among athletes, ranged from 6.50 to 7.22 $m.sec^{-1}$.

Figure 1. Stride length and frequency characteristics of the approach run for all athletes

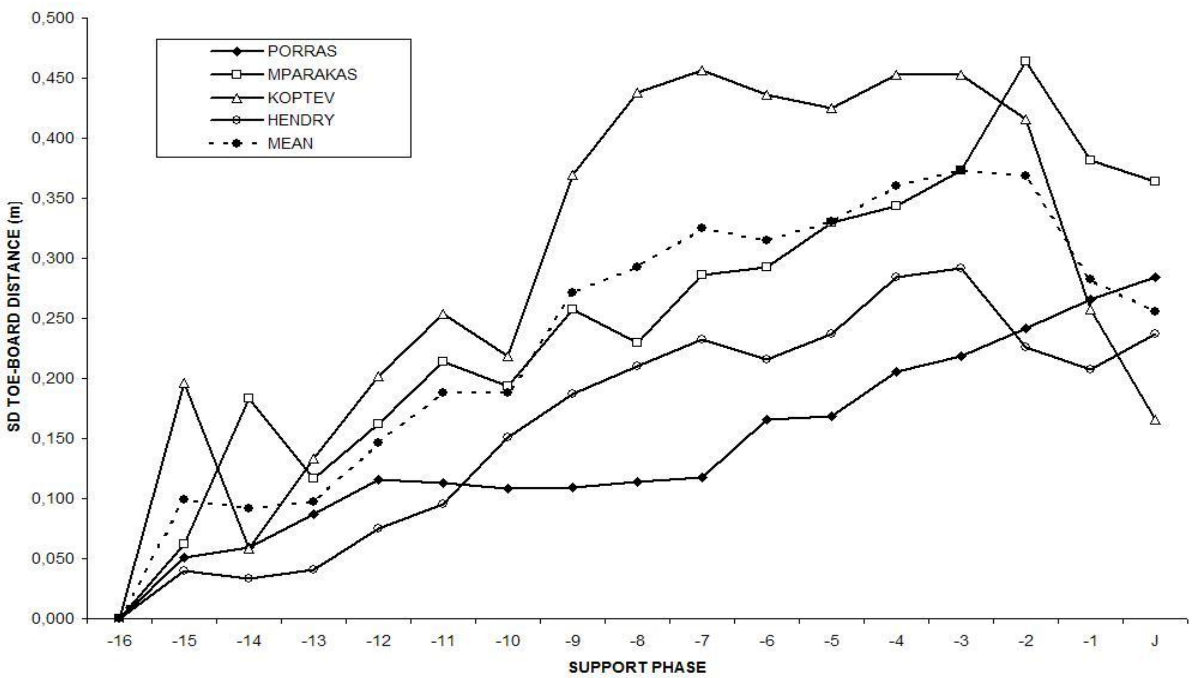


4.2. Stride regulation

Another objective of the current study was to establish the pattern of footfall variability for visually impaired (category B1; no light perception) elite long jumpers in the approach phase of the long jump and weigh the results against the existing data for non-visually impaired expert and novice long jumpers. All the studies investigating stride regulation at the approach phase of long jump have demonstrated that all the athletes irrespective of their expertise display an ascending-descending trend of variability for foot placement over trials. Similarly, at the present study 3 out of 4 athletes demonstrated an initial ascending trend. The SD_{max} of TBD recorded at the present investigation was similar to the values reported in some studies (e.g. 0.37m for Lee *et al*. 1982; 0.33-0.36m for Galloway

& Connor 1999), larger than the values reported in others (0.22m for Hay & Koh 1988; 0.23m for Hay 1988) and considerably smaller compared to novice participants (0.58m Scott *et al.* 1997). As shown on Figure 2, three out of four blind athletes demonstrated an initial ascending mean SD of TBD reaching a maximum value of 0.37m (± 0.08m) on the fourth (mean 3.67 ± 0.58) support phase (i.e. third stride from the board) and at a mean distance of 6.26m (± 0.60m) from the take-off board.

Figure 2. Mean and individual SDs of toe-board distance for the participating athletes



Following the point of maximum SD (SD_{max}) of TBD, a descending trend was recorded for the remaining strides until the take-off board where the mean SD of TBD across trials was reduced to 0.25m (± 0.10m). The descending pattern commenced approximately on the third stride (mean = 2.67) and at a mean distance of 6.26m (± 0.60m) from the take-off board. Although similar trends have been reported by individual athletes of high (Lee et al., 1982) and elite (Galloway & Connor 1999) level, in the majority of the VR studies so far the descending trend commences as an average on the 4th to 5th stride from the board and at a mean distance of 7.48m to 10.0m from the take-off point (Hay 1988; Berg, Wade & Greer 1994; Bradshow 2005).

The average SD of TBD for the take-off stride was 25cm. It is very interesting that VI athletes demonstrate an accuracy of foot placement on the board comparable with non-VI athletes. This value is similar to the one recorded for non-long jumpers (25 cm, Scott et al., 1997), close to the one recorded for novice long jumpers (15cm, Berg, Wade & Greer 1995) and larger to the ones recorded for elite level athletes (6 – 12 cm, Hay & Koh 1988; 4 – 6cm.,Hay 1988). Nonetheless, there have been studies where elite athletes individually, at the take-off stride, had mean TBD of 20 cm (Galloway & Connor 1999). Furthermore, if we take into consideration that the dimensions of the board for B1 athletes is 1 x 1.20m as opposed to 0.20 x 1.20m for non-VI athletes, the takeoff error, proportionally to the size of the board, is considerable smaller for the VI athletes. Therefore, a question is raised as to how VI athletes manage to regulate their stride pattern equally successfully to their non-VI counterparts since visual regulation is not available.

5. Conclusion

The data from the present study suggest that blind athletes demonstrate a level of consistency in their run-up comparable to high level non VI athletes. It is obvious that some sort of regulation is present as it happens to non VI counterparts. The answer to this could be that the task specific experience or an auditory regulation (replacing the absent visual one) or a combination of both comes in effect aiding them to adjust their strides at the final phase of the run-up. According to the IBSA regulations of the event competitors in the B1 Long Jump may use a caller on the run-way to provide acoustic orientation to the athlete during the approach run (IBSA 2009). Hearing or audition is a sense with a strong exteroceptive role, informing us about the nature of movements in our environment but at the same time, like vision, can tell us a great deal about our own movements. Most of the movements we make in the environment produce sounds, such as the footsteps when we are running. The nature of these sounds then provides us with a great deal of information about our actions. To some extend, audition and vision are very similar, providing both exteroceptive and pro-prioceptive information (Schmidt and Lee 2005). Lee (1990) hypothesized that bats can determine time-to-contact (information about the time remaining until a moving object arrives at the eye) based on the acoustic flow field rather than the visual flow field to orient themselves; sounds form objects (exteroceptive feedback) and from their own movements (expproprioceptive feedback) provide information for orienting them within the cave. In similar fashion VI athletes may be exeroceptively guided by their instructor standing near the take-off board guiding them verbally, while expro-prioceptively from the rhythmical sound of their strides as they accelerate down the runway.

6. References

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