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EVALUATING THE APPROACH RUN OF CLASS F11 VISUALLY IMPAIRED ATHLETES IN TRIPLE AND LONG JUMPS[1]

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Summary. —The present study examined stride pattern characteristics of Class F11 visually impaired long jumpers and triple jumpers. Athletes demonstrated initial ascending footfall variability followed by a descending variability, on the second (long jumpers) and third (triple jumpers) stride prior to take-off, at a mean distance of 6.26 m (long jumpers) and 7.36 m (triple jumpers) from the take-off board. Toe-board-distance variability reached a maximum value of 0.36 m and 0.38 m for the long and triple jump respectively. Last stride toe-board-distance variability was 0.29 m (long jump) and 0.25 m (triple jump). Class F11 visually impaired athletes exhibit regulation of goal-directed gait analogous to that of non-visually impaired.

The long jump and the triple jump constitute the horizontal jumps of athletics and share a common technical aspect essential to the athlete's performance, the approach phase. Foot placement accuracy depends heavily on the constancy of the run-up distance, number of strides, and the ability of the athlete to reach maximal controllable horizontal velocity in a similar fashion for all trials.

Lee, Lishman, and Thomson (1982) first reported that placing the foot accurately at take-off in long jump is a demanding task that could not be performed effectively merely by developing a consistent stride pattern. They suggested that at the initial phase of the run-up, athletes develop their speed adopting a stereotyped stride pattern. However, slight deviations inevitably occur in footfall positions (toe-board-distances), which progressively accumulate during the approach to form a substantial variation that must be corrected during the final strides (approximately five) before the athlete hits the board. These findings were confirmed by further studies which investigated the approach phase of long jump (Berg & Mark, 2005; Berg, Wade & Greer, 1994; Bradshaw & Aisbett, 2006; Hay, 1988; Hay & Koh, 1988; Scott, Li & Davids, 1997) or triple jump (Hay & Koh 1988; Maraj, 1999) using a range of performers (elite, high class, skilled, unskilled, and novice long jumpers). All studies reported similar findings and suggested that the final fraction of the long and triple jumper's run-up is regulated and that this regulation is an ever-present element of the event's performance.

These observations gave rise to interesting theories; Lee *et al.* (1982) suggested that stride regulation during the final phase of the run-up was initiated by visual estimation of time-to-contact. The optical variable "tau" was thought to provide this information. The investigators (Lee et al., 1982) suggested that the athlete, through sensitivity to "tau", perceives time-to-arrival to the board and proceeds to a series of spatial-temporal changes in his stride (regulation through vertical impulse of the flight times for the remaining strides) to step accurately on the take-off board. Consequently, the adjustments of stride lengths at the final phase of the approach run emerge as a coupling of one prominent informative variable (tau) and a single type of locomotor control (vertical impulse of foot on the ground), (Berg et al., 1994). This "tau hypothesis" for explaining step length regulation has undergone detailed scrutiny by the researchers. Berg, *et al.* (1994) advocated that perception of time-to-contact is not based exclusively on visual information, but on velocity, distance, or body-scaled metrics. The latter was confirmed by Montagne, *et al.* (2000), who reported that the amount of correction to be made by the athlete was correlated with the amount of correction produced, signifying that athletes use continuous control, based on a perception-action coupling. Later, Berg and Mark (2005) reported their findings to be inconsistent with notions that time-to-arrival with a ground target while running is predominantly specified by an optical tau or a distance/velocity computational strategy and proposed a “multisensory tau hypothesis” which takes into account the athletes’ kinaesthetic perception while the target is localised visually.

All the theories described above stress the importance of vision in the regulation of the approach run in horizontal jumps. However, humans rely on other important sensory inputs as well. For instance, the long jump and triple jump are events of the International Blind Sport Association (IBSA) and Paralympics competition programme as well. Class F11 competitors 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 (IBSA, 2009). The athletes during the jump must wear approved obscure glasses and may use a caller standing next to the board to provide acoustic orientation during the approach run. Jenison (1997) reported that sounds offer certain advantages in the detection of an object when the line of sight is occluded and that the information conveyed, within certain restrictions, is the same.

The assimilation between non-visually impaired and visually impaired long and triple jumping served as motivation for the present study. Both visually impaired and non-visually impaired competitors focus upon their approach phase and develop a maximum controllable horizontal velocity, adjust their body position during the final steps, and aim for optimal foot placement on the board. For non-visually impaired athletes, the role of vision during the approach phase is apparent and described in the literature. However, vision cannot play this role in visually impaired athletes. Following vision, the most important sensory input on which visually impaired athletes rely on is hearing. This is why the competition rules of the event at the specific category allow coaches to provide acoustic guidance to their athletes.

Until now, there has not been any published quantitative and qualitative research studies examining kinematic and spatial-temporal characteristics of the horizontal jumps in visually impaired athletes. The hypothesis that the present study investigated was if a step length regulation is present during the approach run of long jump and triple jump in class F11 visually impaired athletes.

Method

Participants

The four finalists in the men’s long jump (*M* age =31.2 yr., *SD*=5.1; *M* mass =75.75, *SD*=2.9; *M* height =1.80 cm, *SD*=0.03) and the three finalists in the men’s triple jump (*M* age= 31.0 yr., *SD*=6.2; *M* mass=75.7 kg, *SD*= 3.5; *M* height =1.80 cm, *SD*= 0.04), of IBSA 2009 European Athletics Championship participated at the study. All the athletes were classified by IBSA and IPC as category F11 and they all had the same visual acuity, i.e., *"*From no light perception in either eye, but inability to recognise the orientation of a 100M Single Tumbling E target (height: 145mm) at a distance of 250mm (STE LogMAR: 2.6)*"* (IBSA 2011, page 4). These athletes represented the whole population of category F11 visually impaired long and triple jumpers from Europe at that time and constituted a homogenous and representative sample in terms of performance. The competing athletes were obliged by the competition rules to wear obscure glasses through out the event. The take-off area consisted of a rectangle 1 x 1.22m prepared with the use of powder, while jump length is measured from the point of landing in the pit to the nearest impression made by the take-off foot. All other relevant IAAF rules for the long and triple jump competition were applied (IBSA, 2009).

The study was approved by the University's ethics committee and by IBSA. Informed consent was obtained from the athletes and their guides prior to the commencement of the competition. The participants were video recorded during the event's final. A qualification round was not required due to only 4 and 3 visually impaired athletes competing in the championship's long and triple jumps, respectively. The sample, although small in size, may be perceived as homogeneous and representative (in terms of performance) of elite F11 visually impaired long and triple jumpers in Europe.

Procedure

Assessment took place at the athletics stadium during the men's final of the long jump event. The set up for the experimental procedure was performed based on the protocols described by Bradshow and Aisbett, (2006), Galloway and Connor (1999), Hay (1988), Hay and Koh (1988), Lee, *et al.* (1982), Scott, *et al.* (1997). White markers were placed at 1-m intervals on both sides of the runway designating forty 1.0-m zones. This was to allow the measurement of the horizontal distance between the athletes' toe and the proximal to the pit edge of the take-off board (toe-board distance). The run-up of each long and triple jump was recorded with a digital video camera (SONY HDR-SR10) operating at 50 frames/sec. The camera was zoomed in on the athletes' feet and was manually panned to allow the athlete's entire run-up to be recorded. The camera was placed at a distance of 15 m from the midline of the runway and 3m higher from the ground level allowing good visibility of all the markers on the runway. The data collection set up is illustrated in Fig. 1. The procedures used for data collection did not interfere with athletes' participation at the competition. In total, 40 run-ups were recorded and analysed, with a minimum of five jumps per individual subject.

The digital video recordings were transferred to a personal computer and the frames of each foot contact on the ground were captured and transferred for analysis to APAS 2010 (ARIEL DYNAMICS) software. To assess the toe-board-distance in each foot contact, a five-point model was used according to the method described by Hay and Koh (1988) (Fig. 2).

Due to the camera being panned during video recording, the level of filming was not parallel to the line between near markers. Therefore, the validity of the procedure for calculating the toe-board-distance was assessed by recording a panning video with shoes placed on the runway at known distances (0.10m, 1.0m, 2.0m, etc., at 2-m intervals from 3.0m up to 25.0m from the front edge of the take-off board). The toe-board-distance of the calibration shoe was then calculated using the same method as described above. The comparison between the actual shoe distance and the video-recorded distance indicated an error of ± 1 cm. This amount of error was considered acceptable for the purposes of the study and compared favourably with previous investigations (e.g., Lee, *et al.*, 1982, 1cm; Galloway & Connor ± 2%, Hay & Koh, 1988, -1cm to +1.20cm; Scott, *et al.*, 1997, -1cm). In addition, errors associated with the video recording from an elevated height of 3 m was evaluated with the use of a second stationary camera. This stationary camera (CASIO EXF1) was positioned at a distance of 12 m with its optical axis perpendicular to the take-off board, elevated at a height of 2 m, and recorded at a speed of 300 frames/sec. for the final four support phases of the athletes' approach run. The toe-board distances for each of the last four support phases, calculated from the videos filmed with the panning and the stationary camera, were then compared. The differences in toe-board-distance calculation between the two recordings were less than 1%, which again was considered acceptable for the purposes of the study and therefore, only the data obtained with the panned camera was used for the analysis.

Measures

The standard deviation (*SD*) of the toe-board distances for each contact of the athlete's foot across trials was calculated. Stride length was defined as the distance between two successive support phases and it was calculated by the subtraction of the consecutive toe-board distances (Berg & Greer, 1995). Stride regulation was considered to initiate at the support phase at which the maximum *SD* in toe-board distance was recorded, provided that this was followed by a systematic decrease of the *SD* value until the last contact (Berg, *et al.*, 1994; Bradshaw & Sparrow, 2001). The difference between the distance to the board and the mean distance to the board for a given stride (n) across trials for a particular athlete specified the adjustment that was needed (Montagne, *et al.*, 2000). The difference between the length of the subsequent stride (n + 1) and the mean step length across trials for a particular athlete showed the adjustment that was made (Montagne, *et al.*, 2000).

Analysis

Descriptive statistics of toe-board-distance were calculated for each support phase and the mean and *SD* of stride lengths across trials. The distribution of adjustments was analysed according to the method proposed by Hay (1988) as follows:

$$\text{Adjustment (\%)} = \frac{(S_i - S_{i-1})}{(S_{max} - S_j)} \times 100$$

Where S is the *SD* of toe-board-distance, i is the i^{th}-last contact, j is the take-off contact and S_{max} is the maximum *SD* at the assumed onset of regulation.

The intra-step analysis proposed by Montagne, *et al.* (2000) and a parametric Pearson correlation coefficient along with a simple linear regression analysis were used detect any relationship between the adjustment made and the adjustment needed at the last strides of the approach run (i.e. the stride where regulation appeared and thereafter).

Results

General Characteristics of the Approach Run

As shown in Table 1, the approach run of the long jumpers ranged from 29 to 35 meters and comprised 16 strides. For the triple jumpers, the run-up ranged from 25 to 31 meters and comprised 12 to 16 strides. Both long and triple jumpers initiated their run from a standing position, increasing their speed progressively. Among the finalists, average stride length was 200 cm (*SD*=15) for the long jumpers and 206 cm (*SD*=6) for the triple jumpers. The lengths of the last three strides prior to take-off were distributed as follows for the long jump: third to last 207 cm; second to last 233 cm; last 198 cm, and for the triple jump: third to last: 205 cm; second to last: 220 cm; last: 204 cm.

Toe-Board-Distance Variability

For the long jump, as shown in Fig. 3, the athletes demonstrated an initial ascending mean *SD* of toe-board-distance reaching a mean maximum value of 36 cm (*SD*=14) on the third support phase (i.e., second stride from the board) and at a mean distance of 6 m (*SD*=1) from the take-off board. Following the point of toe-board distance when SD_{max} was achieved, a descending trend was recorded for the remaining strides until the take-off board for the mean *SD* of toe-board distance across trials was reduced to 29 cm (*SD*= 5).

For the triple jump, the athletes demonstrated an initial ascending mean *SD* of toe-board distance reaching a mean maximum value of 38 cm (*SD*=21) on the fourth support phase (i.e., third stride from the board) and at a mean distance of 7 m (*SD*=1) from the take-off board. Following the point of toe-board distance when SD_{max} was achieved, a descending trend was recorded for the remaining strides until the take-off board and the mean *SD* of toe-board-distance across trials was reduced to 25 cm (*SD*=18).

Distribution of Adjustments

For the long jump, the adjustment made following the onset of regulation (second stride from the board) was distributed as follows: 65% and 72% for the last and second to last strides, respectively. The Pearson correlation coefficients between adjustment made and adjustment needed (intra-step analysis, Montagne, *et al.*, 2000) were statistically significant only for the second-to-last stride ($r = .75$, $p = .001$) but not for the last stride (1st: $r = .39$, $p = .13$). The simple linear regression analysis for the last stride yielded a non-significant positive $\beta = .39$ ($R^2 = .15$, $p = .14$; $Y_{adjmade} = -.03 + .119*X_{adjneeded}$). For the second to last stride, the results were significant ($\beta = .39$, $R^2 = .64$, $p < .001$) and the respective regression equation was: $Y_{adjmade} = -.002 + .288*X_{adjneeded}$.

For the triple jump, the adjustment made following the onset of regulation (third stride form the board) was distributed as follows: 76%, 36% and 30% for the last, second-to-last, and third-to-last strides, respectively. The Pearson correlation coefficients between adjustment made and adjustment needed (intra-step analysis, Montagne, *et al.*, 2000) were significant for the last ($r = .67$, $p = .006$) and second-to-last ($r = .58$, $p = .02$) strides, but not for the third-to-last stride ($r = .17$, $p = .55$). The simple linear regression analysis for the prediction of the adjustment made from the adjustment needed, revealed a significant positive $\beta =.67$ ($R^2 = .45$, $p = .006$) for the last stride ($Y_{adjmade} = -.002 + .373*X_{adjneeded}$) and a significant $\beta =.58$ for the second-to-last stride ($R^2 = .34$, $p = .02$; $Y_{adjmade} = .003 + .216*X_{adjneeded}$). There was a non significant $\beta =.17$ for the third to last stride ($R^2 = .03$, $p = .55$; $Y_{adjmade} = .001 + .024*X_{adjneeded}$).

Discussion

Comparing the results of the current study with others demonstrates that blind athletes, although not using an optical tau, have consistent run-ups and a pattern of stride regulation comparable to high level non-visually impaired athletes. The maximum *SD* (SD_{max}) of toe-board distance was similar to those reported in some studies (0.37 m in Lee, *et al.,* 1982; 0.33-0.36 m in Galloway & Connor, 1999), larger than the values reported in others

(0.22 m in Hay & Koh, 1988; 0.23 m in Hay, 1988; 0.15 m in Maraj, 1999) and considerably smaller than for novice athletes (0.58 m in Scott, *et al.*, 1997). The descending pattern of variability initiated two strides later for the visually impaired long jumpers and one stride later for the visually impaired triple jumpers compared to reports in non-visually impaired athletes. In visual regulation studies, the descending trend commences as an average on the fourth to fifth stride from the board and at a mean distance of 7.5 m to 10.0 m from the take-off point (Hay, 1988; Berg, *et al.*, 1994; Bradshow & Aisbett, 2006). Another finding was that both visually impaired athletes in long jump and triple jump demonstrated an accuracy of foot placement on the board comparable with non-visually impaired athletes. The values recorded are similar to those reported for non-long jumpers (25 cm, Scott *et al.*, 1997), but higher than the values recorded for novice long jumpers (15 cm, Berg & Greer, 1995), elite long jumpers (7–14 cm, Hay & Koh, 1988; 4–6 cm, Hay, 1988), intermediate triple jumpers (8-10 cm, Maraj, 1999), and elite triple jumpers (9-18 cm, Hay & Koh, 1988). The lower accuracy observed at the last stride in visually impaired athletes compared to non-visually impaired could be due to the size of the board and that the length of the jump is measured from the point of take-off and not from the board's proximal edge to the pit. This allows for a more tolerant placement of the take-off foot in relation to the adjustment needed. Nonetheless, taking into consideration that the dimension of the board for class F11 athletes is 1.00 x 1.22 m as opposed to 0.20 x 1.22 m for non-visually impaired athletes, the take-off error, proportionally to the size of the board, is considerable smaller for the visually impaired athletes.

Between Subject Variability

Significant variations across athletes and sex for the onset of regulation or even complete absence of regulation have been reported for non-visually impaired athletes (Hay & Koh, 1988). Hay and Koh (1988) suggested that this may be due to alternative strategies adopted by some athletes or due to lack of specific training to develop the ability of stride regulation. As shown in Fig. 3, the mean *SD* of toe-board distance clearly demonstrated an ascending trend of variability followed by a descending trend, two and three strides prior to take-off for the long jump and triple jump, respectively. However, when the data of individuals are viewed, not all participants had the same amount of variability. As presented in Fig. 4, among the four long jumpers, one had a continuously increasing ascending trend of variability until the end of the approach run. This suggested that the variability in foot placement for the athlete kept increasing and was not corrected as he approached the take-off board. The triple jumpers, however, all presented an ascending-descending trend of variability (Fig. 5).

As described, a distinctive modification in the long and triple jump rules for class F11 athletes compared to non-visually impaired athletes is the presence of a caller (usually the coach), which assists them in correcting orientation errors but also guides them towards their target. The form of guidance is distinct for each coach and his athlete and is shaped during the training sessions. Usually a few seconds before the athlete begins their approach, the coach, who is standing next to the board, starts shouting rhythmically a tempo sound (e.g. "TAAAK -TAAAK – TAAAK") constantly providing verbal feedback like "you are ok……, keep it straight..., more to the left/right…..". For the long jumper that did not present an ascending-descending trend, this variation could be attributed to the particular manner that the athlete was guided on the take-off board. Every foot contact in his run up coincided with a rhythm given (vocally) by his coach and was progressively increased as he approached the board. Further investigation is required to assess if the method that coaches use for guiding blind athletes affects the stride pattern of the approach run.

Distribution of Adjustment and Origin of Regulation

The majority of the adjustment, both for the long jumpers and the triple jumpers, was distributed over the last two strides of the approach. The present findings are similar, although the values were slightly higher, compared to those reported by Hay (1988) for elite athletes (67%), Berg and Greer 1995 for novice athletes (79%) and Scott, *et al.*, (1997) for unskilled athletes (~50%). The greater proportion of adjustment distribution observed among athletes in the present study may be attributed to the regulation commencing two strides later compared to non-visually impaired athletes, thus causing more cumulative stride correction. Berg and Greer (1995) identified the same pattern of adjustment distribution in novice athletes and suggested that the regulation of the stride lengths in the long jump indicated an interaction between the jumper and environment and reflects action perception coupling in human bipedal motion. The intra-step analysis applied to the strides following the onset of regulation revealed a significant relation between the adjustment needed and the amount of adjustment produced for the second-to-last stride in the long jump and the last two strides in the triple jump. This linear relationship may be interpreted as evidence for the presence of an action-perception coupling. However, since vision is absent in this class of athletes, the nature of the perception guiding them to perform the ascending-descending pattern of variability for foot placement might have a different origin compared to non-visually impaired athletes.

According to Berg and Mark's (2005, p. 523) multisensory tau hypothesis, even without vision, humans are sensitive to their position relative to the proximal support surface and even when vision is absent, runners retain the gait cycle through an acute sense of limb position and movement relative to the body and the support surface. It appears that during the accelerative phase of the approach run, visually impaired long jumpers and triple jumpers mainly used kinaesthetic elements to localize their position. According to the "Difference theory" (Fletcher, 1980) people with visual impairment develop a set of associations with the environment functionally equivalent to those of sighted individuals. This process occurs due to an alternative process based on the theory that when a sense is absent an alternative input can partially compensate in the provision of spatial information (Semwal & Evans-Kamp, 2000). These sensory inputs allow visually impaired individuals to alternatively decode the spatial information, adopting a varied approach for resolving the problem, which is as precise as vision (Semwal & Evans-Kamp, 2000). The ability to rely on alternate sources of information during sport performance is a process mastered with practice and is developed meticulously during the training sessions. Many researchers have suggested that a possible explanation may be due to extensive practice which "automatically" shifts conscious attentional demands on alternate sources of sensory feedback (Abernethy, Neal, & Koning 1994). According to Fleishman and Rich (1963), practice leads to a greater reliance on kinaesthetic rather than ex-proprioceptive information, while other researchers (Smyth & Marriot 1982; Bennet & Davids 1995) suggested that experts are less affected by the loss of visual proprioception than novice performers. Aydog, *et al.*, (2006) reported higher mediolateral postural stability in the visually impaired participating in physical activity than in the sedentary participants with no visual impairment. The F11 long jumpers in the present study had an accuracy of take-off foot placement on the board comparable to sedentary non-long jumpers (Scott, *et al.*, 1997), which supports this theory.

Schmidt and Lee (2005) reported that hearing or audition is a sense with a strong exteroceptive role that informs individuals about the nature of movements in the environment and at the same time, like vision, can provide a great deal of information about movements by providing proprioceptive information. The presence of a caller suggests that audition may play an important role at the zeroing-in phase of the approach and the perceived time-to-arrival. Rosenblum, Carello, and Pastore (1987) stated that listeners were able to estimate time-to-contact through acoustic information, while Schiff and Oldak (1990) reported that blind observers, using exclusively acoustic stimulation, exhibited similar accuracy with sighted observers when judging impeding collision. Further, Lee (1990) hypothesized that bats can estimate 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. Sounds from objects (exteroceptive feedback) and from own movements (ex-proprioceptive feedback), provide information for orientation within the cave. Similarly, visually impaired athletes may be exteroceptively aided by their instructor standing near the take-off board guiding them verbally, as well as ex-proprioceptively from the rhythmical sound of their strides, the sense of limb position, movement, and overall the maintenance of balance throughout the gait cycle. Specifically, the acoustic information provided by a coach may be used as a time-to-arrival signal to initiate modification of step length to compensate for previous errors as athletes approach the take-off board. However, the reliance on the coaches' acoustic feedback for perceiving the adjustment may explain the delayed onset of regulation (two strides later) compared to non-visually impaired athletes. Regulation of the approach run is therefore not produced by a single actor, but rather by the duo of athlete and coach, which may delay the coupling of perception to action. The earlier example of the long jumper who did not regulate stride length may indicate that technique, include stride regulation, may be the consequence of the athlete-coach interaction in the approach run. It is possible that the intonation of the coach contained information degrading the appropriateness of the current strides due to not being able to accurately appreciate the athlete's need to increase or decrease his stride length.

Conclusion

The findings of the study support the hypothesis that class F11 visually impaired long jumpers and triple jumpers exhibit a similar ascending-descending trend of toe-board distance variability and distribution of adjustment compared to non-visually impaired athletes. The limitation of the small population and sample size does not allow generalisation of the findings without caution. The method used by the athletes to adjust their stride pattern without visual information is still not clear, since no data were obtained regarding the control exerted through vertical impulse on the flight times of the strides where regulation was observed. Further information could also be retrieved by interviewing both the participants and their guides to understand the interaction of the athlete-coach duo. The acoustic sensory input provided by the coach, along with a highly developed kinaesthesia, may allow the visually impaired athlete to perceive his position relative to the proximal support surface. This observation could have several practical applications in the training of blind athletes. The auditory feedback provided by the coach could be manipulated appropriately to train athletes to optimise accuracy. For example, it may be more critical that the auditory feedback provided by the coach (volume and intonation) does not interfere with the athlete’s running rhythm but acts as a reference for the impending target in a similar fashion that a car bumper alarm indicates an imminent collision: a series of increasingly loud/frequent sounds as the athlete approaches the board. Sound devices with these characteristics could be fabricated and used in training so as to assist athletes to attain more efficient running patterns which will be later used in competition.

Further research is required to investigate the athlete-coach interaction during acoustic guidance. In addition, the variability of foot placement should be examined in class F12 and F13 visually impaired athletes where, according to the rules of the event, acoustic guidance by the coach is not allowed, in order to build a strong theoretical background to support future researchers examining visually impaired jumpers.

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Table 1. Performance and approach run data of the long jump (*n*=4) and triple jump (*n* = 3) participants.

Athlete	Best Jump (m)	Mean performance (m±*SD)*		Number of strides	Run up length (m)	Mean stride length of run-up (cm±*SD*)		TBD and SDmax (m)	Support phase of SDmax
Long jump									
1	5.97	5.81	*0.10*	16	35.27	216.25	*26.51*	5.59 (0.34)	3rd to Last
2	5.90	5.74	*0.17*	16	33.50	208.22	*16.77*	-* (0.37)	Last
3	5.71	5.56	*0.13*	16	31.52	194.56	*23.27*	6.46 (0.56)	4th to Last
4	5.45	5.26	*0.18*	16	29.89	182.92	*24.14*	6.75 (0.30)	4th to Last
Triple jump									
1	12.75	12.66	*0.12*	14	29.93	211.62	*22.67*	8.13 (0.50)	5th to Last
2	12.40	11.88	*0.44*	12	25.76	209.75	*30.21*	7.62 (0.13)	4th to Last
3	12.27	11.86	*0.66*	16	31.75	196.96	*22.85*	6.34 (0.52)	4th to Last

** No ascending –descending trend of Toe-Board Distance variability was recorded*

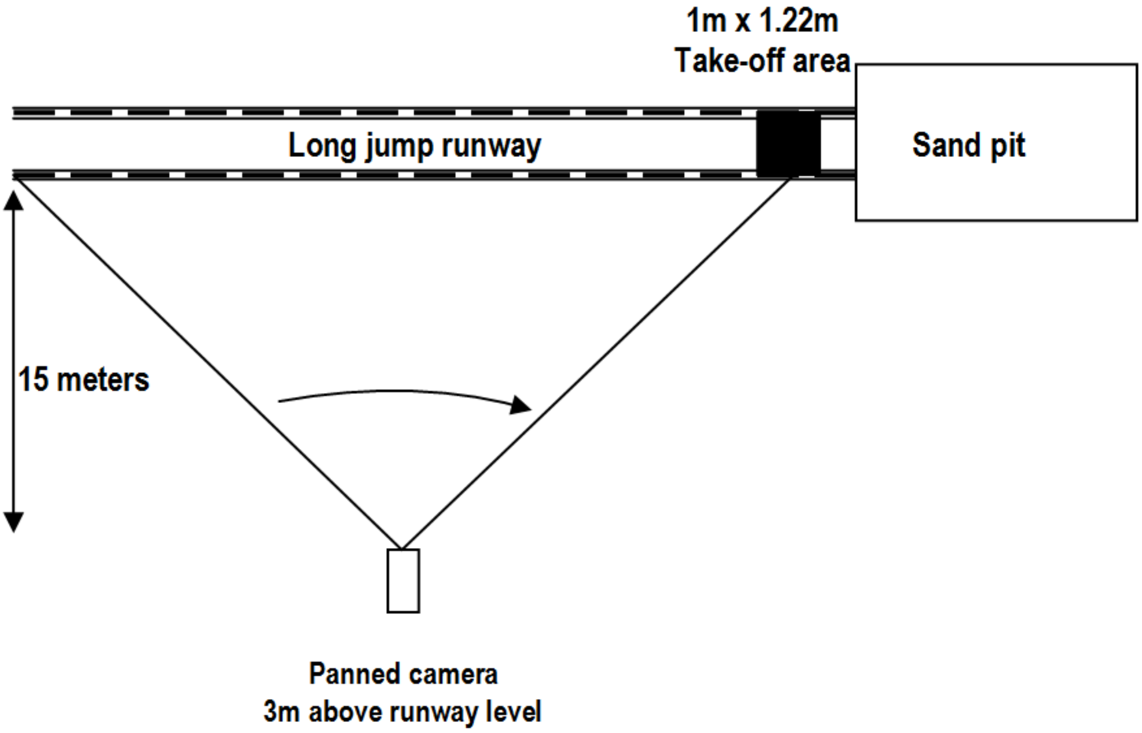

Figure 1. Set up of the experimental procedure

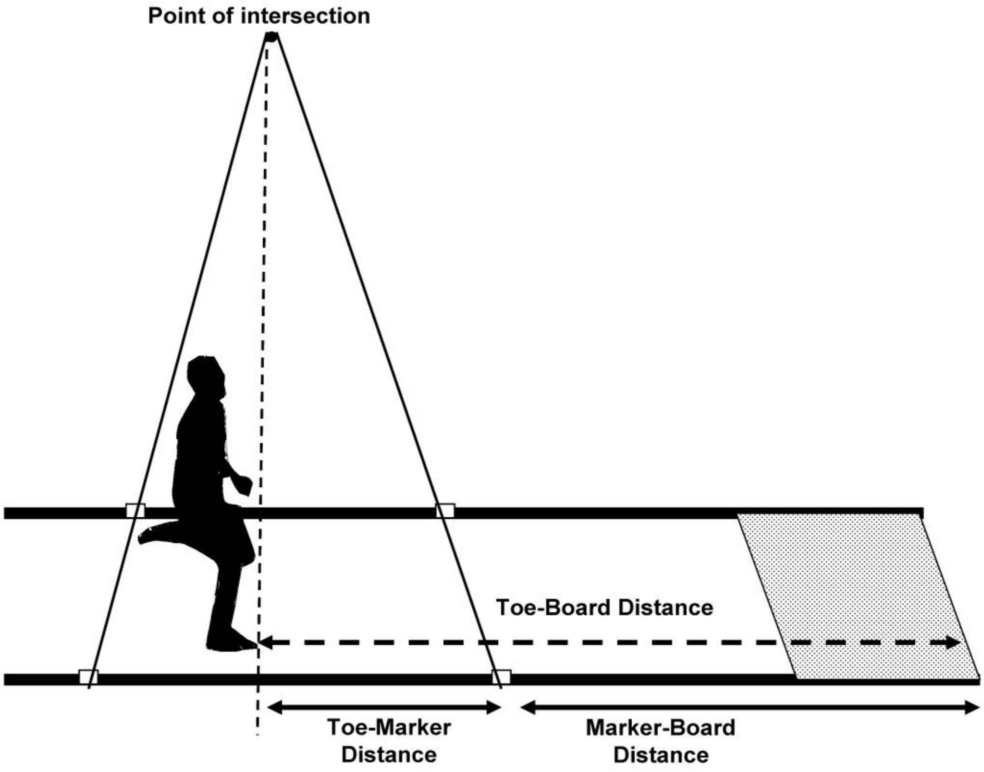

Figure 2. Calculation of Toe-Board Distance

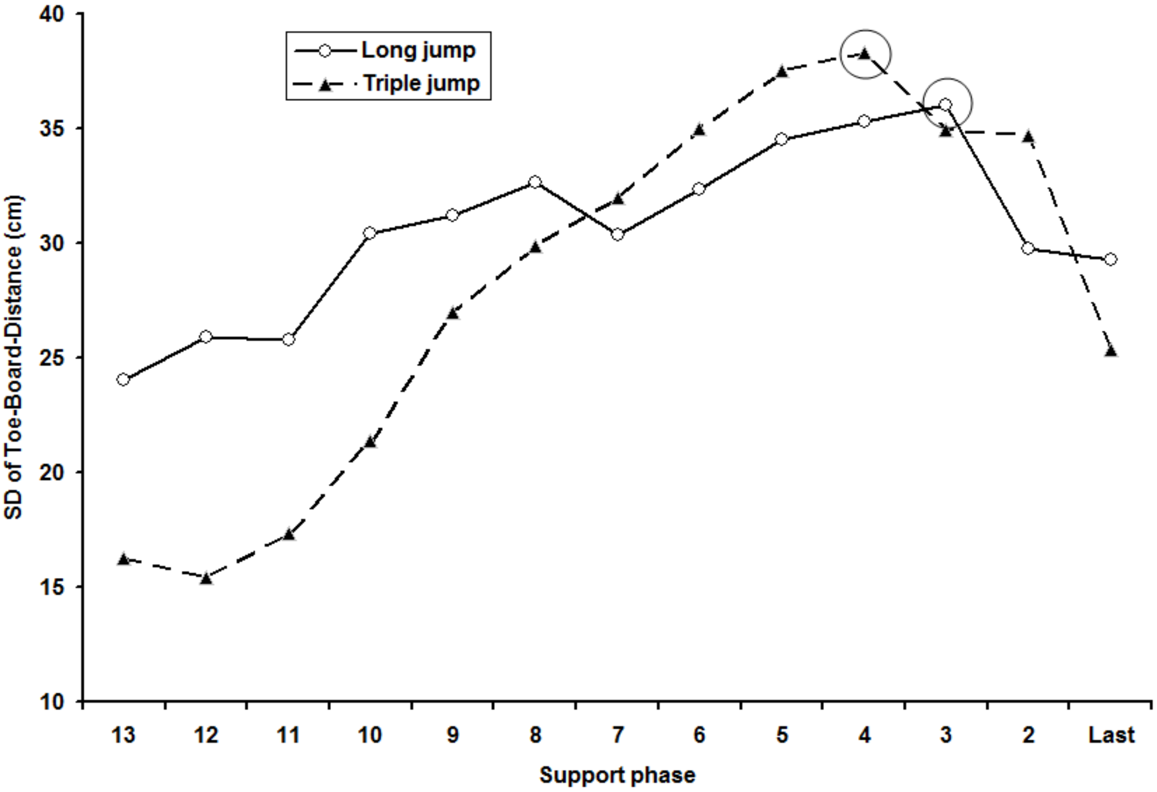

Fig. 3. Mean SD of Toe-Board Distance and onset of regulation (marked in circle) for long jump and triple jump participants at each support phase

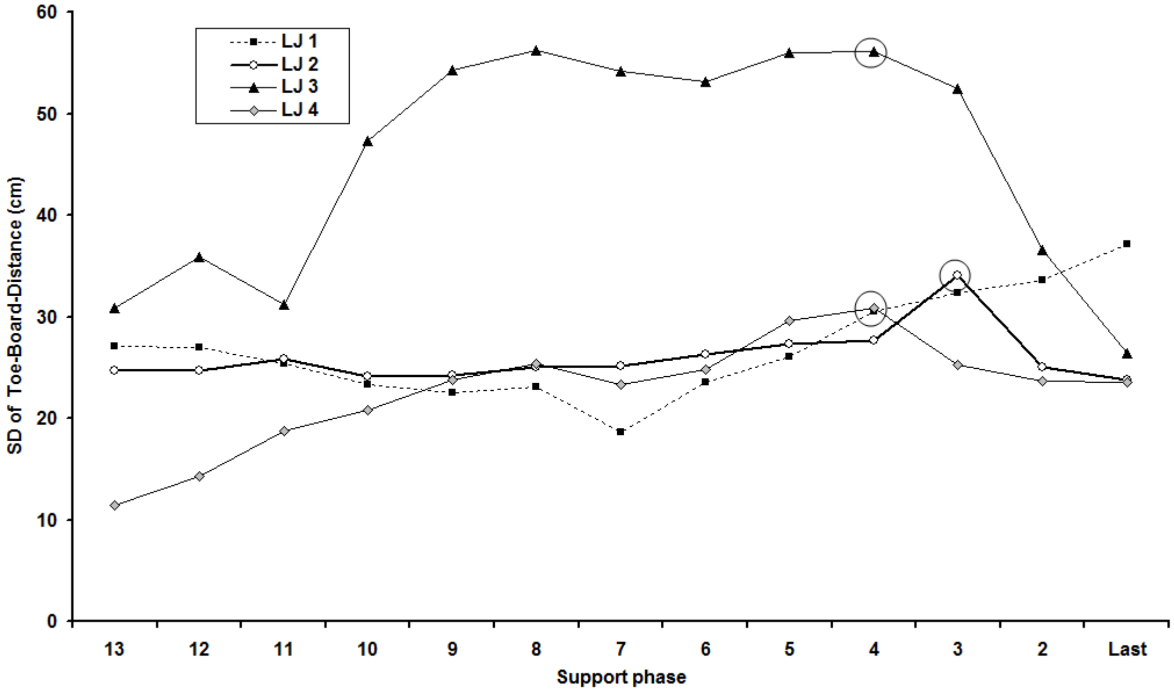

Fig. 4. SD and SDmax (marked in circle) of Toe-Board Distance in each support phase for each long jumper (*n*=4)

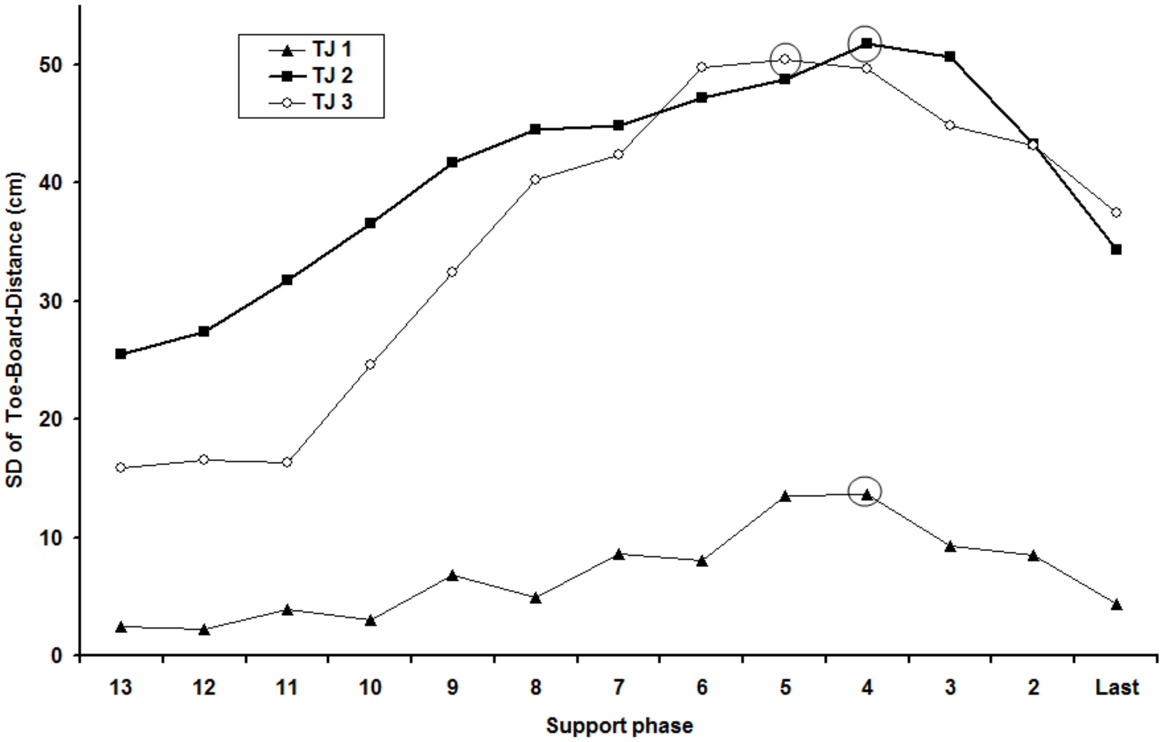

Fig. 5. SD and SDmax (marked in circle) of Toe-Board Distance in each support phase for each triple jumper (*n*=3)

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