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INFLUENCE OF VISUAL IMPAIRMENT LEVEL ON THE REGULATORY MECHANISM USED DURING THE APPROACH PHASE OF A LONG JUMP[1]

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Summary.—The purpose of the study was to investigate the occurrence of stride regulation at the approach phase of the long jump in athletes with normal vision and visually deprived Class F12 and F13 athletes. All the athletes exhibited the presence of a regulatory mechanism. In the normal vision group this occurred on the fifth-to-last stride. In Class F12 athletes regulation commenced on the fourth-to-last stride for males and third-to-last stride for females. Class F13 males commenced regulation, like the control group, on the fifth-to-last stride; but females commenced on the fourth-to-last stride. The study demonstrated that reduced vision does not prevent Class F12 and F13 athletes from applying a regulatory mechanism similar to that observed in sighted athletes. However, the control mechanism of regulation emerged earlier in non-visually deprived long jumpers and the least visually impaired Class F13 athletes, signifying the importance of visual function in the regulatory stimuli.

Experienced athletes have notable coherence between their actions and the demands of their sporting environment. Although their locomotive patterns appear to be reproduced with high stability, even under strong pressure, the pattern of movements is not stereotyped. Instead, they seem to be fine-tuned and harmonized to the continuous input of information from their surroundings (Williams, Davids, & Williams, 1999). Undoubtedly, a competitor should achieve an early attainment of the spatio-temporal characteristics of the action environment so that coordination of the musculoskeletal system can be coordinated in time. This is mainly accomplished by vision-guided information processing (Fitch & Turvey 1978; Lee, 1980; Turvey, 1990), although other sensory inputs are essential as well. Perception is a process that identifies and interprets fluctuations in the forms of energy flowing through the environment, such as light rays and sound waves through neural activation of a large population of neurons (Bruce,

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Green, & Georgeson, 1996). However, it is widely accepted that visual perception is the leading source upon which the sport performer relies to meet the task constraints (Lee, 1978; Cutting, 1986).

Long jump is a task that has been extensively used in the investigation of motor control, due to the restraints imposed on the actor (athlete). Success in the long jump is primarily determined by an effective completion of the approach phase, which in turn profoundly depends on the consistency of the stride length, number of strides, and pattern of speed development across all attempts (Hay, 1986). The physiognomy of the event has made it popular among researchers exploring the motor behaviour of athletes (Lee, Lishman, & Thomson, 1982; Hay, 1988; Hay & Koh, 1988; Berg & Greer, 1995; Scott, Li, & Davids, 1997; Bradshaw & Aisbett, 2006), and as a means to verify the views of Gibson (1979) and ecological psychology for the relation between perception and action (Montagne, Cornus, Glize, Quaine, & Laurent, 2000). Research evidence suggests that long jumpers regulate the final 4–5 strides of the run-up, using visually guided information to achieve precise foot placement on the board. The time-to-contact estimation of the athlete approaching the take-off board is dominated by the tau hypothesis, which proposes that a quantity (tau) present in the visual stimulus provides the necessary information (Tresilian, 1999).

Nonetheless, the visual trail is not available to all long jumpers. Long jump is one of the events of the Paralympics competition, where three classes of athletes with different levels of visual loss participate. Competing athletes are classified into three categories (F11, F12, and F13) in relation to the level of visual impairment [International Blind Sports Federation (IBSA), 2011], defined by associated changes in visual acuity and/or visual field [World Health Organization (WHO) 1980, p. 205]. Visual acuity describes the ability of the eye to perceive detail and is usually measured using a chart which contains letters decreasing progressively in size. In Snellen's notation (Snellen, 1862), visual acuity is defined as the distance at which the person can recognize a letter, divided by the distance at which a person with normal eyesight can do this. Thus, a visually impaired long jumper, with a Snellen visual acuity of 6/60, can barely see an object at a distance of 6 meters (approximately 3 strides from the board) that a non-visually impaired would be able to see at 60 meters. Visual field refers to the ability to detect objects in the periphery of the visual environment. The normal forward-facing binocular field of vision is about 210 and 90 degrees in the horizontal and vertical planes, respectively. Visual field-loss will manifest itself in an inability to detect peripheral objects and, often, in a reduced ability to avoid obstacles.

Athletes participating in Class F11 have no light perception in either eye, or visual acuity poorer than 2/60 (IBSA, 2011; International

Paralympic Committee [IPC], 2011). During competition, F11 athletes must wear approved opaque glasses blocking out any light. The visual acuity of a Class F12 athlete should range between 2/60 and 6/60, and/or their visual field should be constricted to a diameter of less than 5 degrees (IBSA, 2011; IPC, 2011). Class F13 athletes have a visual acuity ranging from 2/60 to 6/60 and/or a restricted visual field diameter of less than 40 degrees (IBSA, 2011; IPC, 2011). Class F13 long jump athletes compete under the International Amateur Athletics Federation (IAAF, 2012) competition rules as athletes with normal eyesight (IBSA 2011), using a standard take-off board, i.e., a 0.20 m × 1.22 m white rectangle. A larger, white take-off board (1.00 m × 1.22 m) is used for F11 and F12 classes, and the competitors may also use a caller (usually the coach) to provide acoustic feedback during the approach run (IPC, 2011).

Theodorou and Skordilis (2012) recently reported that Class F11 long and triple jumpers exhibited a regulation pattern during the approach run similar to the one observed in sighted athletes, but initiated on the third-to-last rather than the fifth-to-last stride. The authors advocated that the acoustic sensory input provided by the coach probably allowed Class F11 athletes to perceive time to arrival to the proximal take-off board and act by regulating their strides. This observation suggests that visual information may not dominate the regulation-control mechanism for these athletes. The purpose of the study was to test the following hypotheses:

Hypothesis 1. The control mechanism of stride regulation at the approach phase of the long jump is present in Class F12 and F13 athletes, as in athletes with normal vision.

Hypothesis 2. The control mechanism of regulation emerges on a different stride in Class F12 and Class F13 athletes, and in athletes with no visual impairment.

Method

Participants

The finalists in the long jump events of the IBSA European Athletics Championship held in June 2009 in Greece participated in the study. The F12 group comprised five men (*M* age = 28.5 yr., *SD* = 6.0) and five women (*M* age = 28.0 yr., *SD* = 6.0), with personal best performances ranging from 6.62 m to 6.81 m and 5.41 m to 5.85 m for men and women, respectively. The F13 group comprised four men (*M* age = 25.5 yr., *SD* = 7.0) and six women (*M* age = 24.0 yr., *SD* = 4.0), with personal best performances ranging from 5.79 m to 7.18 m and 4.96 m to 5.61 m for men and women, respectively. The above-mentioned sample was selected because of the official classification of the athletes as F12 or F13 by IBSA's and IPC's medical boards, and the confidence that the respective athletes formed a group representative of elite Class F12 and F13 long jumpers. IBSA provided permission for the research. Finally, a group of 7 female long jumpers with no visual impairment and personal best performances ranging from 5.20 m to 5.92 m (*M* age = 24.0 yr., *SD* = 0.7) served as a control group. All participants had knowledge about the aim of the study and an informed consent was obtained according to the University research ethics code.

Procedure

Class F12 and F13 athletes were recorded during the actual competition of the IBSA 2009 European Athletics Championship, while the control group's performances were recorded on a separate occasion. The same experimental procedures were applied for all groups (F12, F13, and control). The participants were recorded with a panning digital video camera (SONY HDR-SR10, Sony Electronics, Inc.) operating at 50 frames/sec. The camera was fixed on a tripod, which was positioned on the stands at a 15 m distance from the midline of the run-up lane and at 3 m height from ground level (Fig. 1). The camera was manually panned and it was zoomed in on the athletes' feet for recording each participant's entire run-up. For the execution of the panned, two-dimensional video-analysis, 0.05 m × 0.05 m custom reference markers were placed on either side of the lines defining the runway, and formed one-meter zones along the entire runway. The calibration of the field of view and the panning procedure was conducted following the instructions proposed by Gervais, Bedingfield, Wronko, Kollias, Marchiori, Kuntz, *et al.* (1989). The camera positioning allowed all markers to be visible on the captured motion of interest. The experimental set-up for data collection did not disturb the athletes' effort throughout the event, in the judgment of the authors and coaches.

All participants performed 6 trials each. Every single trial was recorded, but the fault attempts were excluded from the analyses. Each athlete performed at least 5 legal jumps. In total, 154 legal run-ups were included in the analysis (n = 59, n = 55, and n = 40 for F12, F13, and control groups, respectively). The video frames of each foot touchdown on the ground were extracted from the selected video recordings. The method suggested by Chow (1987) and adjusted by Hay and Koh (1988) was used for the determination of the exact touchdown distance, which was calculated with respect to the closest marker (toe-marker distance, TMD) and to the proximal to the pit edge of the take-off area (toe-board distance, TBD). TMD was calculated by projecting the position of the athlete's shoe toe at the instant of touchdown onto a line between the two near markers, through a digitization process using the APAS 2010 software (Ariel Dynamics Inc., Trabuco Canyon, CA). TBD was then calculated by the addition of the TMD and the marker-board distance (Fig. 1). This procedure was repeated for every footfall in all the analysed run-ups.

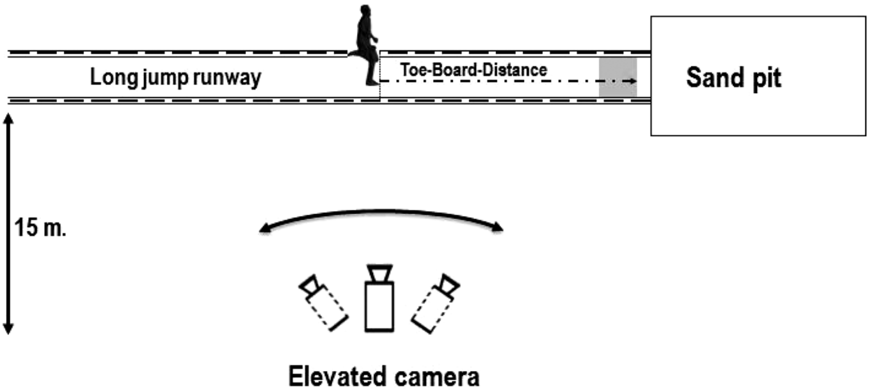

FIG. 1. Set up of the experimental procedure

In order to assess the error of the panning recording, the four last footfalls of the athlete's run-up were recorded with a stationary digital CASIO EX-FX1 (Casio Computer Co. Ltd., Shibuya, Japan) video camera (sampling frequency: 300 frames/sec). The camera was elevated 1.2 m from the ground and fixed on a rigid tripod, which was positioned 12 m from the midline of the run-up lane and at a distance of 1.0 m before the beginning of the take-off area. The optical axis of the camera was perpendicular to the plane of motion. The recorded area was calibrated by consecutively placing a 2.5 m × 2.5 m frame, with 16 reference markers. Each athlete's toes at every support phase were manually digitized using the APAS 2010 software (Ariel Dynamics Inc., Trabuco Canyon, CA). The set-up and the entire procedure for the execution of the 2D-DLT analysis were done according to Kollias (1997). The extracted coordinates of the athlete's shoe toe at the instant of touchdown was then compared to the TBD obtained from the panning analysis. Differences concerning the TBD extracted from both analyses were found to be negligible (0–0.5%). Additionally, the validity of the method to determine the TBD was assessed by comparing the outcome of the above-described procedure, using videos captured with a panned motion identical to the one of the actual recordings. These test videos recorded shoes placed on the runway at known distances (0.10 m, 1.0 m, 2.0 m, 3.0 m, and every 2.0 m afterwards up to 25.0 m from the front edge of the take-off board). TBD obtained by the video analysis was then compared with the actual TBD, which revealed an error of ± 1%, an error within range of those found in similar studies (Lee, *et al.*, 1982: 1 cm; Hay & Koh, 1988: –1 cm to +1.20 cm; Scott, *et al.*, 1997: –1 cm; Galloway & Connor, 1999: ± 2%). Based on these findings, the data from the panning recordings were used for assessing the parameters used in this study.

Data Analysis

To identify the incidence of regulatory patterns and make comparisons with what is reported in the literature regarding its occurrence (Lee, *et al.,* 1982; Hay, 1988; Hay & Koh, 1988; Berg & Greer, 1995; Scott, *et al.,* 1997; Bradshaw & Aisbett, 2006), an inter-trial analysis was used. This analysis takes into account the variability of the distance between the athlete's toe and the board (toe-board distance, namely TBD) for a given stride across all trials. Foot placement variability for a particular stride was expressed by the standard deviation of TBD (TBD_{SD}) for each footfall of a participant, across all of the athlete's trials (Lee, *et al.,* 1982; Hay & Koh, 1988; Berg, Wade, & Greer, 1994). The point where stride regulation appeared was defined as the footfall at which the maximum value of TBD_{SD} (TBD_{SDmax}) was recorded, providing that it represented the peak of an ascending trend, followed by an immediate descending trend (Berg, *et al.,* 1994). The accuracy of targeting the take-off area was reflected by the TBD_{SD} of the footfall at the take-off area (TBD_{SDto}). For better comprehension, the point at which stride regulation commenced was also expressed as the distance from the take-off line.

The percentage distribution of adjustment ($ADJ_{\%}$) in each one of the regulated strides was calculated for each participant following the method suggested by Hay (1988), with the *means* computed as:

$$ADJ_{\%} = \frac{\left(TBD_{SDi} - TBD_{SDi-1}\right)}{\left(TBD_{SD\max} - TBD_{SDto}\right)} \times 100 \qquad \text{[Equation 1]}$$

where i is the i^{th}-to-last contact.

Results

Toe-board Distance (TBD) Variability by Group

Class F12.—The analysis of the pattern of footfall variability in each participant revealed that the TBD*SD* presented a systematic ascending–descending trend for all athletes, men and women. The acute decline in footfall variability in men commenced as an average on the 4th-to-last stride from the take-off area (two athletes on the 5th-to-last stride, and three subjects on the 4th-to-last stride) at a *mean* distance of 9.09 m (*SD* = 0.26) after reaching a *mean* value of 0.34 m (*SD* = 0.057). Likewise in women, this occurred on the 3rd-to-last stride from the take-off area (one athlete on the 4th-to-last stride, and four on the 3rd-to-last stride) at a *mean* distance of 6.28 m (*SD* = 0.26) after reaching *a mean* value of 0.226 m (*SD* = 0.685). Subsequently, the *mean* TBD*SD* was finally reduced at take-off to a minute TBD*SDto* of 0.09 m (*SD* = 0.049) and 0.08 m (*SD* = 0.014) for men and women, respectively (Fig. 2).

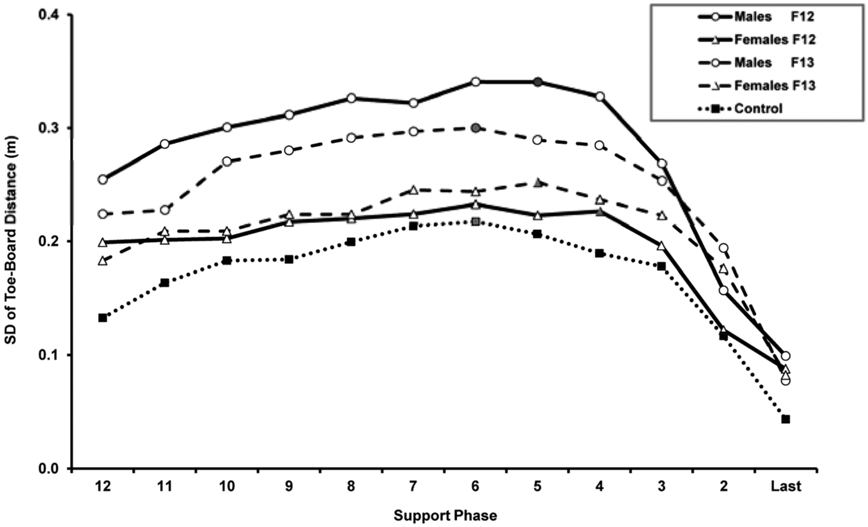

FIG. 2. Trend of *mean SD* of toe-board distance for Class F12, F13 male and female and Control female long jumpers at each support phase. Grey shape in each respective group indicates the onset of regulation.

Class F13.—Male athletes demonstrated a progressively increased *mean* TBD_{SD} that reached a maximum value of 0.30 m ($SD = 0.19$) on the 5th-to-last stride (one on the 6th-to-last stride, two on the 5th-to-last stride, and one on the 4th-to-last stride), at a *mean* distance of 10.84 m ($SD = 0.29$) from the take-off board. Female athletes also demonstrated the same trend and reached a maximum *mean* TBD_{SD} of 0.25 m ($SD = 0.14$) on the 4th-to-last stride (three athletes on the 5th-to-last stride, two on the 4th-to-last stride, and one on the 3rd-to-last stride), and at a *mean* distance of 8.24 m ($SD = 0.55$) from the take-off board. Following this point, a descending trend was recorded for the remaining steps until the *mean* TBD_{SD} was finally reduced to 0.07 m ($SD = 0.06$) and 0.08 m ($SD = 0.02$) for men and women, respectively.

TABLE 1
PERCENTAGE DISTRIBUTION OF THE ADJUSTMENT MADE FOR ALL PARTICIPANTS

Gender	4th-to-last Stride	3rd-to-last Stride	2nd-to-last Stride	Last Stride
F12 men	23%	26%	44%	22%
F12 women	12%	16%	42%	23%
F13 men	10%	20%	26%	41%
F13 women	6%	17%	21%	54%
Control women	18%	12%	32%	48%

Control group.—In female athletes of the control group, *mean* TBD_{SD} reached a peak value of 0.22 m (SD = 0.12) on the 5th-to-last stride from the board (four athletes on the 5^{th}-to-last stride and two on the 4^{th}-to-last stride) at a mean distance of 9.77 m (SD = 0.67) from the take-off point. At the last stride *mean* TBD_{SD} was reduced to 0.04 m (SD = 0.02).

Distribution of Adjustments

The $ADJ_{\%}$ for all the participants in all groups is presented in Table 1.

Discussion

The first aim of the current study was to identify the presence of a regulatory mechanism in athletes with different levels of visual impairment (as defined by IPC) during the locomotor task of the long jump. The results of the study cohered with those reported in the literature and supported the hypothesis that regulation is present irrespective of the amount of visual deprivation. Two segments could be identified during the approach phase for all participants. At the first segment the toe-board distance variability was gradually increased until it reached a peak value. Following this peak, a second segment commenced and variability was markedly decreased as the take-off area was approached. This descent in variability, according to the literature (Hay, 1988; Hay & Koh, 1988; Berg & Greer, 1995; Scott, *et al.,* 1997; Galloway & Connor, 1999; Bradshaw & Aisbett, 2006) denotes the perception of the board primarily through activation of visual processes (optical tau), which supplies the crucial information to the control mechanism to calculate the time to contact. The similarity of the amount of variability, compared to what has been reported in sighted athletes of various levels of expertise (0.37 m in Lee, *et al.,* 1982; 0.22–0.27 m in Hay, 1988 and Hay & Koh, 1988; 0.33–0.36 m in Galloway & Connor, 1999), is not surprising and confirms the findings of Theodorou and Skordilis (2012), who reported TBD_{SDmax} values of 0.36 m and 0.38 m for Class F11 long jumpers and triple jumpers, respectively. These data confirm the first hypothesis of the study and demonstrate that visually impaired athletes, although severely deprived of the "dominant" optical tau, are able to perceive time-to-contact to the take-off area, and act in a regulatory manner.

Furthermore, as hypothesised, not all the groups initiated regulation at the same instant. In Class F12 athletes, the process of perceiving the error and acting for its rectification commenced one (in men) or two (in women) strides later compared to the control group and to previous reports for sighted athletes (Hay, 1988; Hay & Koh, 1988; Berg, *et al.,* 1994; Scott, *et al.,* 1997; Berg & Mark, 2005; Bradshaw & Aisbett, 2006). Class F13 athletes, on the other hand, performed regulation like the non-visually impaired participants of the control group, with a descending pattern of variability, commencing approximately on the fifth-to-last stride (men) and fourth-to-last stride (women) before the take-off board. For all groups, the highest proportion of the adjustment was spread over the last two strides (Table 1). This was comparable with the pattern observed in athletes without visual impairment (67% in Hay, 1988; 79% in Berg & Greer, 1995). F12 participants, however, seemed to perform most of the adjustment on the second-to-last stride rather than on the last stride, compared to the F13 and control groups. This process could be attributed to the fact that in Class F12 the board is considerably wider and the length of the jump is measured from the point of take-off and not from the board's proximal edge of the pit, allowing for a constraint-free placement of the take-off foot. The accuracy of the take-off stride constitutes a constraint indicative of spatial perception, both for sighted athletes and athletes with visual impairment. Class F13 long jumpers demonstrated a precision of foot placement on the board, comparable with non-visually impaired athletes. The *SD* of toe-board distance recorded for the take-off stride for F13 and F12 long jumpers resembled that of the control group and those recorded for elite-level athletes (0.04–0.06 m, Hay, 1988; 0.06–0.12 m, Hay & Koh, 1988) and was considerably superior to novice long jumpers (0.15 m, Berg & Greer, 1995) and non-long jumpers (0.25 m, Scott, *et al.*, 1997).

As shown in Table 2, all the participating athletes in this study regulated the final portion of their approach runs. All non-visually impaired and 90% of Class F13 athletes commenced regulation on the 4^{th}-to-last stride or earlier, as compared to 60% of Class F12 long jumpers. Construing these findings aside the observations of Theodorou and Skordilis (2012), that Class F11 long jumpers with no light perception commenced their regulation on the 2^{nd}-to-last or 3^{rd}-to-last stride, it is hinted that the onset of regulation is de-escalating as the visual impairment increases. The source of this variation must be the visual impairment increasing from Class F13 to Class F11. Nevertheless, within each group, not all athletes commenced regulation on the same stride. Variations across athletes and gender for the onset of regulation have been reported both for non-visually impaired (Hay, 1988) and Class F11 (Theodorou & Skordilis, 2012) athletes. One possible source of this variation in the present study may be the magnitude of visual impairment for each athlete within a class. A Class F12 or F13 athlete with visual acuity of 6/60, for example, may have better estimation of the location of the board compared to an athlete with a 3x reduced visual acuity of 2/60. Moreover, reduced visual acuity coupled with visual field defects could have a major affect on mobility and orientation, since vision provides feedback on the location of targets with respect to the body and assists in calibrating subsequent body movements (Rossignol, 1996; Warren, Jr., Kay, Zosh, Duchon, & Sahuc, 2001). Two forward-facing F13 long jumpers with similar visual acuity, but different amounts of visual field defect, especially in the vertical plane, will have equal ability

TABLE 2

PERCENTAGE DISTRIBUTION OF THE ONSET OF REGULATION BETWEEN AND WITHIN THE GROUPS OF PARTICIPANTS

Stride	*n*	Stride Starting Regulation			
		6th-to-last	5th-to-last	4th-to-last	3rd-to-last
Control women	6		67%	33%	
Class F13	10		50%	30%	10%
Men	4	10%	50%	25%	
Women	6	25%	50%	33%	17%
Class F12	10		20%	40%	40%
Men	5		40%	60%	
Women	5			20%	80%

to perceive the board from a distance, but may differ in their sensitivity to detect it as they are approaching it, which is expected to affect the pattern of regulation of their strides. However, since the examination and classification of the athletes is performed exclusively by the medical boards of IPC (IPC, 2011), any information regarding the exact visual acuity and visual field was not disclosed.

Another probable source of variation at the onset of regulation could be the origin of visual impairment or any previous visual experiences. Literature suggests that there is a difference between adults with acquired and congenital deprivation of vision in the way they monitor the location of objects, as well as their locomotion, balance, and postural control (Millar, 1994; Semwal & Evans-Kamp, 2000; Schwesig, Goldich, Hahn, Müller, Kohen-Raz, Kluttig, *et al.*, 2011). However, this parameter is neither measured, nor does it constitute a classification criterion for IBSA or IPC; athletes' classification is based on the current visual impairment and not on its cause or history. According to Sherrill (1999), classification constitutes an essential feature in disability sports, ensuring that winning or losing depends on training, skill, motivation, fitness, and talent, and not on unevenness among the competitors or a variety of disability-related variables. The range of disability must be small to ensure that most athletes are eligible for viable competition within each class, and that athletes with the greatest disability would not be unduly disadvantaged when compared to athletes with less disability (Tweedy, 2002). In the current study, it was assumed that Class F13 and F12 athletes competing at the 2009 IBSA European Championship constituted homogeneous groups, and were classified by IPC's medical boards in the particular classes, taking into account that athletes within a group are not disproportionately advantaged or disadvantaged to each other. This poses a limitation in the study, but the variations observed in some competitors regarding the onset of regulation could be used to investigate the even-handedness of the classification system used by the IPC. Future studies should look into this issue.

Summarising, the current investigation suggests that visually impaired long jumpers demonstrate a pattern of foot placement variability and take-off accuracy comparable to high-level sighted athletes, during the approach run. Nevertheless, a question is raised concerning the processes assisting F12 and F13 athletes to accomplish such accuracy. Although vision controls locomotion for humans, self-perception studies of walking without visual feedback reveal that self-motion perception does not cease when the eyes are closed (Thomson, 1983; Rieser, Ashmead, Talor, & Youngquist, 1990; Loomis, Da Silva, Fujita, & Fukusima, 1992; Rieser, Pick, Jr., Ashmead, & Garing, 1995). Durgin, Pelah, Fox, Lewis, Kane, and Walley (2005) postulated that the perception of self-motion is multimodal, and recalibration of movement may occur in response to differences between visual, vestibular, haptic, kinesthetic, and motor estimators. According to Berg and Mark's (2005) multisensory tau hypothesis, even without adequate vision, runners can maintain gait through an acute sense of limb position and movement, relative to the body and the support surface. Other studies (Fletcher, 1980; Deshpande & Patla, 2007; Hallemans, Ortibus, Meire, & Aerts, 2010) have reported that visually impaired people develop adaptive sensory modalities, in terms of locomotion and postural control, functionally equivalent to those without visual impairment. This process takes place by integrating alternative sensory inputs, which alternatively decode the spatial information, and allows them to use an adaptive approach equally effective with that of the sighted population (Semwal & Evans-Kamp, 2000). For instance, Aydog, Aydog, Cakci, and Doral (2006) reported a higher mediolateral postural stability in blind people participating in physical activity than sedentary sighted people. Sensitivity to exteroceptive cues (spatio-visual) plays a dominant role while an individual is learning a new perceptual-motor task. As performance becomes habitual, however, proprioceptive feedback and kinesthesis become more important (Fleishman & Rich, 1963). According to Williams, *et al.* (1999), sporting action involves considerably more than the aptitude to “see.” The oxymoron of having sight, yet performing successfully without being able to see well, has led many researchers (Starkes & Deakin, 1984; Abernethy & Russell, 1987; Williams, Davids, Burwitz, & Williams, 1992) to support that “perceptual skill is more a function of the expertise attained through practice rather than the capacity of the system that receives the various signals” (p. 61). The latter is also confirmed in the current study: F12 and F13 long jumpers exhibited less variability in toe-board distance and notably superior accuracy in take-off foot placement compared to what has been reported for sighted non-long jumpers or novices (Berg & Greer, 1995; Scott, *et al.*, 1997). It is also possible that the influx of visual information in this particular class of athletes, although limited, was adequate for the completion of the locomotor task at hand. In Class F12 for example, although the rules of the event allow for a caller to stand next to the board and provide voiced guidance, athletes competing at elite levels rarely make use of such an acoustic aid, and none of the participants of the present study did. This indicates that, for the particular group, the visual input available, although limited, was probably adequate for the completion of the locomotor task at hand, and the acoustic cue did not offer any additional succour.

It could be claimed that the visual function of class F12 and F13 athletes, although reduced, is adequate for the spatio-temporal requirements of the event. A decisive factor in long jump performance, and an ever-present feature of the athletes' technique, is the attainment of a proper upright body posture throughout approach and during take-off. Coaching manuals and scientists stress the importance that athletes avoid gazing towards the board, as this would have a detrimental effect on body posture and speed development, but to fixate the gaze beyond it (Schmolinsky, 1983; Berg, Wade, & Greer, 1993; Tansley, 2004; Linthorne, 2005). To that purpose, coaches emphasize during training the attainment of an approach run with an initial stereotyped gait pattern, with its final portion regulated using peripheral vision to provide both exteroceptive and proprioceptive information. In that sense, sighted athletes, to compete successfully in the long jump, need to develop the kinesthetic and proprioceptive skills of their visually impaired counterparts, who can easily master, through practice, the stereotyped portion of the run-up. It appears the long jump is an event where class F13 athletes could train and compete alongside sighted competitors. The world record performance in class F13 long jump (7.64 m and 5.88 m for men and women, respectively) could easily rank, in some countries, among the medallists of a national track and field championship for sighted athletes.

Conclusion

The main finding of the study was that stride regulation is a process present in sighted as well as in visually disabled Class F12 and F13 long jumpers. The control mechanism of regulation emerges earlier in athletes with normal vision compared to Class F13 and F12 athletes. Between the two groups, Class F13 athletes commence regulation earlier compared to F12 athletes. This signifies the importance of visual perception (when present) as regulatory stimuli. Future research should focus on the nature of the sensory inputs employed in the long jump and the manner that spatio-temporal parameters, such as velocity, ground contact times, and stride flight times are manipulated by visually impaired athletes during the final portion of the approach run.

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