APPROACH SPEED, LAST STEP CHARACTERISTICS AND TAKE-OFF ACCURACY OF T36 CLASS PARALYMPIC LONG JUMPERS

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The purpose of this study was to examine the approach speed (V_{APP}), the characteristics of the last three steps and the accuracy of foot placement at the take-off board (TTB) in T36 Paralympic long jumpers. Nine male finalists in the T36 Class long jump event who competed at the 2012 London Paralympics were analyzed using high speed video cameras and a speed radar gun. Results revealed that V_{APP} (8.0 ± 0.4 m/s) peaked at a distance of 6.40 ± 3.25 m from the take-off board. Both parameters were significantly correlated with the effective distance of the jump. TTB was 0.14 ± 0.10 m. There was no indication that the last steps were performed using the adequate step length for the proper execution of the “larger penultimate – shorter last step” technique. The adoption of this technique when approaching the take-off board may improve the effectiveness of the approach and aid in achieving a better take-off.

KEYWORDS: cerebral palsy, co-ordination impairment, biomechanical analysis, radar gun measurements, step parameters, sport performance.

INTRODUCTION: Athletes with co-ordination impairments (hypertonia, ataxia and athetosis) can compete in Classes T35 to T38 long jump events in the Paralympic Games (Tweedy, 2010). In the T36 Class, competitors demonstrate the above impairments which affect all four limbs, but the upper extremities are similarly or more affected than the lower extremities. This imposes a limitation when performing an explosive movement such as the long jump. During the approach, a Paralympic long jumper may achieve the desirable maximum speed that he/she is capable of, but will not be able to perform the take-off effectively, resulting in a rather limited jumping distance (Tweedy, 2010).
Previous studies have analyzed the approach run of Paralympic long jumpers with transtibial and transfemoral amputation (Padulles et al., 2019) and visual impairments (Theodorou et al. 2013; Torralba et al., 2017), with specific research interest in the final steps of the approach and the accuracy of touchdown at the take-off board. This interest is due to the effectiveness of the “larger penultimate – shorter last step” technique for the step length regulation (Hay & Nohara, 1990), which allows for a larger gain in vertical take-off velocity without an extensive loss of the acquired horizontal velocity (Bruggemann and Conrad, 1986). However, para-athletes with co-ordination impairments demonstrate inferior performance in explosive motions such as jumping and strength tests compared to able-bodied athletes (Beckman et al., 2016; Reina et al., 2018). It is therefore possible that the impaired coordination in the arm swing might contribute to less balance (Mann, 1981) in T36 Class long jumpers during the

sprint phase of the approach and consequently may result in a reduced ability to regulate the length of the final steps. Thus, the purpose of the study was to examine the relationship of performance, approach-run speed, step characteristics at the final stage of the approach and the accuracy of the foot placement at the take-off board in elite T36 Class long jumpers. The results of this study could provide useful knowledge for coaches and practitioners to improve training and overall performance of Paralympic long jumpers competing in T36 Class.

METHODS: The approach run of nine male finalists in the T36 Class long jump event in the 2012 London Paralympics was analyzed. Approval for the investigation was obtained from the University's Ethics Committee and the International Paralympic Committee (IPC).
Custom 0.05 x 0.05 m reference markers were placed at 1-m intervals on both sides of the run-way. Two EX-F1 (Casio Computer Co. Ltd., Shibuya, Japan) cameras operating at a sampling frequency of 30 fps were set to record in high definition (1280x720 pixels) the attempts of the jumpers. The cameras were fixed on tripods and placed within the spectators' area. The cameras were approximately 20 m from the run-way and 5 m elevated from the ground, with their optical axis perpendicular to the run-way. One camera was placed 10 m prior the take-off board, while the other was parallel with the take-off board. The recorded videos were digitized using the APAS Wizard 13.3.0.3 software (Ariel Dynamics Inc., Trabuco Canyon, CA). The analysis was performed on the frames that captured foot contact on the ground in each of the last three steps and the touchdown on the board. Toe-board distance (TBD), namely the horizontal distance between the athlete's toe and the proximal to the pit legal edge of the take-off board, was calculated according to Theodorou et al. (2017). The accuracy of the foot placement at the take-off board (TTB) was measured in the same manner. The effective jumping distance (S_{EFF}) was the official distance added the TTB. Step length (SL) was the difference in TBD between two consecutive footfalls of the opposite legs. Step frequency (SF) was the number of steps executed in 1 s. The examined temporal parameters were contact (T_C) and flight (T_{FL}) times, as well as the T_{FL} to T_C ratio (T_R).
The speed of the approach was measured using a Stalker ATS 5.02 radar (Applied Concepts Inc., Plano, TX), acquiring data at a frequency of 48 Hz. The radar was positioned 10 m from the back end of the long jump pit and at a height of 1.2 m. Thus, during the entire approach runway, there was a direct sight of the jumpers' torso. After completing the data reduction procedure as presented by Padulles et al. (2019), the maximum value of the speed attained during the approach-run (V_{APP}), the distance of its occurrence from the take-off board ($V_{MAX}BD$) and the average velocity on the take-off board (V_{BO}) were extracted (Figure 1).

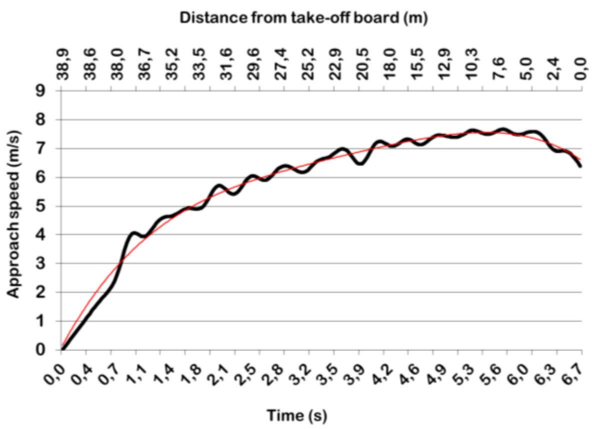

Figure 1: Representational graph of the speed progression of a T36 Class long jumper in relation with time and the distance from the take-off board.

Descriptive statistics are presented as mean value ± standard deviation. Normality of distribution was assessed using the Kolmogorov-Smirnov test (p > .05). The differentiation of SL and SF among the three last steps was checked with one-way ANOVA. Significant differences were followed up with a Scheffe post hoc analysis. The relationship of the approach parameters and S_{EFF} was tested with a Pearson's correlation. For all tests, the IBM SPSS Statistics v.25 software (International Business Machines Corp., Armonk, NY) was used, with the level of significance set at *a* = .05.

RESULTS: The results of the examined approach and take-off parameters are presented in Table 1. The official distance and TTB were 4.92 ± 0.29 m and 0.14 ± 0.10 m respectively, resulting in a S_{EFF} of 5.06 ± 0.32 m. V_{BO} was 17.9 ± 4.5% lower than V_{APP}. Pearson's correlation analysis revealed a strong positive linear relationship between S_{EFF} and V_{APP} (r = .85, p = .008), while S_{EFF} was strongly, negatively correlated with V_{MAX}BD (r = -.88, p = .004). As for the step parameters, SF (F = 9.817, p = .001) but not SL (F = .813, p = .455) was significantly differentiated in the last three steps. The observed difference in SF was due to the differences in T_{FL} rather than T_C (F = 17.454, p < .001 and F = .645, p = .533, respectively) among the last three steps. Finally, post hoc analysis revealed that T_R for the penultimate step (namely: step 2; 1.05 ± 0.08 s) was significantly different compared to the third-to-last step (0.86 ± 0.26 s, p = .032) and the last step (0.59 ± 0.21 s, p < .001).

Table 1: Results for the examined parameters (*n* = 9).

Parameter	mean		SD
SL_3 (m)	1.99	±	0.23
SL_2 (m)	2.09	±	0.26
SL_1 (m)	1.94	±	0.24
SF_3 (Hz)	3.97	±	0.35
SF_2 (Hz)	3.60	±	0.46
SF_1 (Hz)	4.43	±	0.38*
V_{APP} (m/s)	8.0	±	0.4
V_{MAX}BD (m)	6.40	±	3.25
V_{BO} (m/s)	6.6	±	0.6

*NOTE: 1,2,3: the number of the step prior the take-off board; *: p = .001 SF_1 vs. SF_2.*

DISCUSSION: The aim of this study was to examine the approach parameters in elite male T36 Class long jumpers. The approach velocity observed in the present study (8.0 ± 0.4 m/s) was considerably lower than in able-bodied long jumpers competing in major competitions (10.0-10.3 m/s; Panoutsakopoulos et al., 2017). This confirms previous research reporting that T36 Class sprinters are slower than able-bodied athletes because of the reduced horizontal force and power production ability (Antunes et al., 2017; Bezodis et al., 2020).
It is also of interest to note that the further from the take-off board the maximum approach velocity was achieved, the longer the jump distance was. This is an indication that the execution of the final steps did not facilitate a further augmentation of the approach speed. It seems that the increased requirements in co-ordination for the execution of the last steps with the "larger penultimate – shorter last step" technique (Hay & Nohara, 1990) imposes a constraint to T36 Class long jumpers, as the arm and leg movements have to be coordinated under conditions of maximum velocity (Macadam et al., 2018). However, the rhythmic pattern (as indicated from the flight to contact time ratio; T_R) was similar to the one reported for able-bodied long jumpers (Panoutsakopoulos et al., 2017). Finally, approach speed was significantly correlated with the jumping distance, indicating that the examined jumpers could effectively execute the take-off. Thus, the technical elements responsible for this finding should be defined in future studies. Research so far suggests that runners with brain impairments have reduced step length and increased contact times compared to non-disabled runners (Fiorese et al., 2020). This trend was also observed in the examined Paralympic long jumpers. The extensive loss of horizontal velocity at the take-off reveals that Paralympic long jumpers with co-ordination impairments had an inferior performance in an explosive motion like the take-off for the long jump as generally evident in jumping and strength tests compared to able-bodied athletes (Beckman et al., 2016; Reina et al., 2018). Thus, as asymmetries and imbalances were also previously found in athletes with cerebral palsy during strength and power tests (Antunes et al., 2017), a holistic approach involving the

reliance and symmetry in the step parameters (Theodorou et al., 2017) should be introduced in the training process of Paralympic long jumpers. This approach may improve the technical execution of the final steps of the approach and thus might be beneficial for performance improvements in T36 Class long jumpers.

CONCLUSION: Elite male T36 Class long jumpers attained an efficient approach speed, but poorly executed the technique of the last two steps of the approach. As the run-up in long jump is a demanding targeting task under the constraint of maximum speed, the findings derived from this study may provide assistance for clinical practice in the future.

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