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ORIGINAL ARTICLE

Relationships between take-off speed and performance in F-44 and F-46 paralympic discus throwers

Relações entre a velocidade de decolagem e desempenho em lançadores de disco paraolímpicos da classe F-44 e F-46

Relaciones entre la velocidad de despegue y el rendimiento en los lanzadores de discos paralímpicos de las clases F-44 y F-46

Túlio Luiz Banja Fernandes[a], Saulo Fernandes Melo de Oliveira[b*], José Igor Vasconcelos de Oliveira[c], Felipe José Aidar Martins[d], Valdir Rodrigues Ramos Júnior[a], Manoel da Cunha Costa[e], Tetsuo Tashiro[f]

Keywords:
Biomechanics;
Paralympic athletics;
Discus throw;
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ABSTRACT
This study aimed to analyze discus throwing in Paralympic athletes from two functional classes (FCs). Seven athletes from two classes F-44 (N=4) and F-46 (N=3) performed three throws each during a regional competition and were evaluated through 3D kinemetry. The assessed athletes presented a similar throwing technique, with a preparation movement opposite to the throw preceding the shot. Class F-44 showed a weak correlation between take-off speed and range (r= 0.15; p>0.05). F-46 showed a strong correlation between take-off speed and range (r=0.77; p=0.014). We conclude that athletes from the assessed FCs present important differences in terms of performance.

Palavras-chave:
Biomecânica;
Atletismo paralímpico;
Lançamento do disco;
Classificação funcional.

RESUMO
O presente estudo teve como objetivo a análise do lançamento de disco em atletas paralímpicos de duas classes funcionais (CFs). Sete atletas de duas classes F-44 (N=4) e F-46 (N=3) executaram 3 lançamentos cada durante uma competição regional, e foram avaliados por meio de cinemetria 3D. Os atletas avaliados apresentaram uma técnica de lançamento semelhante, com movimento de preparação em direção oposta ao lançamento que antecedia o arremate. Na classe F-44 houve uma fraca correlação entre a velocidade de decolagem e o alcance do disco (r= 0,15; p>0,05). Na F-46 houve forte correlação entre a velocidade de decolagem e o alcance (r= 0,77; p=0,014). Conclui-se que atletas das CFs avaliadas apresentam diferenças importantes em termos de desempenho.

Palabras clave:
Biomecánica;
Atletismo paralímpico;
Lanzamiento de disco;
Clasificación funcional.

RESUMEN
El presente estudio tuvo como objetivo analizar el lanzamiento de disco en atletas paralímpicos de dos clases funcionales (FC). Siete atletas de dos clases F-44 (N = 4) y F-46 (N = 3) realizaron 3 lanzamientos cada uno durante una competencia regional, y fueron evaluados usando cinemetría 3D. Los deportistas evaluados presentaron una técnica de lanzamiento similar, con un movimiento de preparación en sentido contrario al lanzamiento que precedió al tiro. En la clase F-44 hubo una correlación débil entre la velocidad de despegue y el alcance del disco (r = 0,15; p> 0,05). En el F-46 hubo una fuerte correlación entre la velocidad de despegue y el alcance (r = 0,77; p = 0,014). Se concluye que los deportistas de los CF evaluados presentan importantes diferencias en cuanto a rendimiento.

[a]Universidade Federal do Ceará – UFC, Instituto de Educação Física e Esportes. Fortaleza, CE, Brasil.
[b]Universidade Federal de Pernambuco – UFPE, Núcleo de Educação Física e Esportes. Vitória de Santo Antão, PE, Brasil.
[c]Universidade Federal de Pernambuco – UFPE, Programa de Pós-graduação em Educação Física – PPGEF. Recife, PE, Brasil.
[d]Universidade Federal de Sergipe – UFS, Departamento de Educação Física. São Cristovão, SE, Brasil.
[e]Universidade de Pernambuco – UPE, Escola Superior de Educação Física. Recife, PE, Brasil.
[f]Universidade Federal de Pernambuco – UFPE, Núcleo de Educação Física e Esportes. Recife, PE, Brasil.

***Corresponding author:**
Saulo Fernandes Melo de Oliveira
E-mail: saulofmoliveira@gmail.com

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INTRODUCTION

Assessments in adapted sports have attracted the attention of trainers and researchers, interested in optimizing sports performance. Paralympic sports are structured through a functional classification system that assesses the motor performance and capacity through a point count for muscle function, joint mobility, limb length, with the function of ensuring equity during competitions (Higgs et al., 1990). Different deficiencies lead to different mechanical responses, and it is important to characterize movement kinematics to understand and maximize sports performance. Athletics is among the disciplines with the greatest potential for medals in Brazil, substantially contributing to the final medal table (https://www.paralympic.org).

In Paralympic sports, there are procedures for the functional classification of athletes aimed at ensuring equity during competitions regarding disability (Higgs et al., 1990). Athletes with disabilities who compete in field events in athletics are classified through an empirical process that involves reviewing medical reports as well as observations during training and competition (Tweedy et al., 2010; Tweedy and Vanlandewijck, 2011). Currently, studies have been proposed to verify the correctness of eligibility criteria relating the functional classification of athletes to performance (Chow and Mindock, 1999; Frossard, 2012).

Some studies have assessed the Paralympic discus throw focused on kinematics parameters (Frossard et al., 2007, 2013c, d). These studies have shown that the variable speed, height, and angle of take-off are determining parameters in the performance of this event (Morriën et al., 2017) and have been systematically present in most biomechanical assessments of this modality (Hay and Yu, 1995; Chow and Mindock, 1999). Athletes have control of throw parameters, which are closely linked to their technique. Among the kinematic factors, take-off speed is the main variable that determines the discus range when both angle and height remain constant (Frohlich, 1981) and air resistance is neglected (Banja, 2004); however, these variables are yet to be better investigated regarding Paralympic athletes who throw standing.

In the Olympic discus throw (in which athletes shoot standing up) the correlations between take-off speed and discus range may vary (r= .39 to .99) (Banja, 2004), and in the Paralympic throw, take-off velocity is also correlated to discus range (Yu et al., 2002) and functional classification (Frossard et al., 2010). However, take-off speed is lower in Paralympic throwers, partly either due to difficulty in performing body rotation towards the throw or to the simple fact of throwing sitting. Paralympic athletes can throw standing or using seated support. All athletes seated on the support are in the F-50 class (F-52 to F-58), while those who throw standing are classified in the F-40 class (F-41 to F-46), even with deficiencies in the lower limbs. In this way, athletes with only one lower limb amputation could compete in the F-40 class using their prosthesis (stand) or in the F-50 class (sitting). When throwing seated, this athlete would have a higher rating (close to F-58), which would lead to competing with athletes with similar abilities.

The use of support in F-50 class is a factor that levels athletes, especially those with considerable deficits in voluntary control and volume of activity in the trunk region. For seating throwers, there are important competitive advantages with the use of auxiliary posts for athletes to hold, in addition to fixing bases for support (Seo et al., 2016; Guimarães et al., 2018). Athletes who are amputated in the upper or the lower contralateral limb are classified in class F-40 and have the ability to rotate through the throwing phase. Studies on athletes in the F-50 class have already been extensively investigated in the literature (Chow and Mindock, 1999; Frossard, 2012); however, so far, no study has verified the kinematic relationships between discus throw and range in athletes of this F-40 class during competitions.

Each of the main throwing variables that influence the discus range correlate to the results of the test in a particular way and also between them. By doubling the take-off speed the range quadruples (Bartlett, 1992), a one-meter increase in take-off height can improve the range two meters (Frohlich, 1981). This means that the best take-off angle will also be linked to both speed and height at take-off. Although some functional classes have eligibility restrictions (protection types and motor differences), throwing type requirements are often used as techniques. Therefore, likewise to the required eligibility, it is also necessary to develop functions that consider both the differences in scientific requirements to provide a greater contribution to the scientific requirements as well as the more functional classes.

In this sense, it becomes necessary to verify whether at lower speeds there are still strong correlations between the discus range and whether athletes can optimize such variables to the point of maximizing performance. There is no information about kinematic indicators in Paralympic throwers who perform their technique at the upright position. These indicators will assist coaches and athletes in selecting posture correction and training methods. Thus, this study aimed to assess the kinematics of discus throwing in athletes from the F-44 and F-46 classes who throw in a standing position. Based on this, we hypothesize is that F-44 class throwers will present lower correlation values between take-off speed and range compared to F-46 class throwers.

METHODS

RESEARCH AND GENERAL CHARACTERISTICS OF VOLUNTEERS

This is correlational descriptive research. Seven athletes from two functional classes F-44 (n=4) and F-46 (n=3) according to the International Paralympic Committee (IPC) aged 32±8 years; height of 171±6 cm;

body weight of 72.8±9.6 kg were assessed during a regional Paralympic athletics competition. One athlete in class F-44 had an amputation and the others had muscle atrophy in one of their legs. Athletes in the F-46 class had unilateral amputation at the level of the surgical colon proximal to the humerus. Table 1 presents descriptive data, including technical details, for each athlete participating in the research. This research was previously authorized by the event organization and registered with the institutional ethics committee under registration number 3.655.538.

KINEMATIC DISCUS THROW ANALYSIS

Assessment was carried out during a regional Paralympic championship. Each participant performed was warmed up for the competition. Participants who performed three throws each and the results were recorded. All athletes throw without executing the spin technique, starting the preparation phase until the finishing phase at a fixed location. Three synchronized cameras (120 Hz) were used to assess the take-off speed. For the 3D calibration, a calibrator with 24 reference points was used. The measured error coefficient between the image and the calibrator was 0.0057 for the X-axis, 0.0043 for the Y-axis, and 0.0113 for the Z-axis. Software Motus V.4.2 (Vicon Peak, Oxford, UK) was used for data analysis. The discus resulting take-off speed after it leaves the thrower's hand completely. The discus range assessment was the same as the official results of the competition.

STATISTICAL ANALYSIS

We performed a descriptive analysis in advance using the mean, standard deviation, in addition to verifying the data normality through Shapiro-Wilk test. Pearson's correlation was used to assess the relationship between take-off speeds and their respective ranges. Individualized correlation coefficients (for each functional class) were considered, as well as the total sample of athletes. All throws performed by the athletes in the three proposed attempts were considered. Correlation coefficients indicate the following correlation degrees: between 0.9 and 1.0 – very high, between 0.7 and 0.9 – high, between 0.5 and 0.7 – moderate, and between 0.3 and 0.5 – low correlation (Witz et al., 1990; Weir, 1999). Complementarily, a regression analysis was used in order to verify the degree of dependence between the take-off speeds and discus range. Analyses were performed on the Prism software, version 8.0 (GraphPad, USA), considering a significance level of 5% (p<.05).

Table 1. Qualitative description of the functional classes and respective motor limitations observed in each of the assessed athletes.

ID athlete	FC group	Main limitation description
01	F44	Atrophy in the musculature of the right leg and slight incapacity in the arms
02	F44	Atrophy in the musculature of the left leg and thigh
03	F44	Atrophy in the right leg and thigh
04	F44	Left leg atrophy below the knee
05	F46	Left arm amputation at the proximal surgical colon
06	F46	Left arm amputation at the proximal surgical colon
07	F46	Left arm amputation at the proximal surgical colon

Legend: ID (Athlete identifier code); FC (functional classification).

RESULTS

Table 1 presents descriptive data of all athletes assessed. A total for 21 throws were computed, being 12 executed by F-44 athletes and 9 by F-46 athletes. Figure 1 shows one of each athlete's attempts for each class.

Table 2 shows the individual values for each thrower carried out. The take-off speed values were higher in the F-44 class than the F-46 class.

In class F-44, the values between take-off speed and range showed low correlation (r=.15; p=.64). In contrast, in class F-46 the values between take-off speed and range of the disc showed a high correlation (r=.77; p=.014). Similarly, when considering all the athletes with their respective throws, correlations considered low, but significant, were found between take-off speed and range (r=.45; p=.04). Figure 2 shows the contributions of the resulting velocities for each analyzed functional class, as well as for all subjects together.

The contribution of the take-off speed on the discus range showed to vary according to the functional class, being around 60% for class F-46 (Figure 2, panel B) and less than 3% for class F- 44 (Figure 2, panel A). Overall, the resulting velocity contributed about 20% to the discus range considering the entire sample assessed herein (Figure 2, panel C).

DISCUSSION

This study aimed to assess the kinematics of discus throwing in athletes from the F-44 and F-46 classes who throw in standing position. We found important differences between the correlations presented when observing the behavior of the two classes of athletes. Our findings suggest that athletes belonging to the F-44 class have less dependence on take-off speed resulting from the implement and discus range. As for the F-46 class, this same behavior is not observed when analyzing contributions.

The athletes in our study, despite performing the discus throw standing up, did not perform the throw using the rotation technique, which normally occurs in high-level athletes. Athletes performed some oscillations and preparatory rotations of the upper limbs and trunk

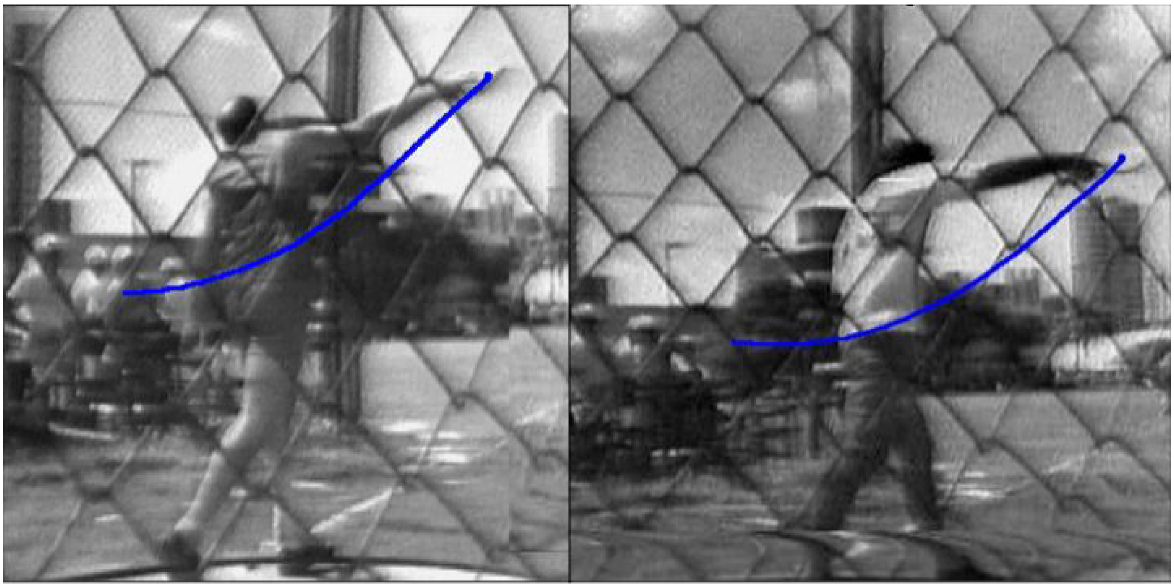

Figure 1. Images of the best athletes' throws in the F-44 (Left) and F-46 (Right) classes, the blue line shows discus trajectory during the acceleration phase until take-off.

Table 2. Descriptive data of each throw performed by all athletes participating in the study.

Athlete (functional classification)	Throw/ attempts (number)	Take-off speed (m/s)	Range (m)
A (F-44)	1	6.95	14.23
	2	10.19	14.70
	3	13.43	15.17
B (F-44)	1	12.75	17.31
	2	11.30	18.56
	3	5.90	17.85
C (F-44)	1	8.15	18.02
	2	4.53	19.57
	3	5.95	17.33
D (F-44)	1	14.58	17.77
	2	18.58	18.06
	3	14.15	22.73
E (F-46)	1	6.95	13.70
	2	10.19	14.60
	3	13.43	14.62
F (F-46)	1	12.69	21.47
	2	14.38	22.73
	3	15.21	23.25
G (F-46)	1	14.04	18.62
	2	15.65	20.84
	3	16.60	21.83

before throwing the disc, with the throwing upper limb fully extended, similarly to athletes who throw on chairs (O'Riordan and Frossard, 2005), thus contributing to a shorter range.

It is worth highlighting that both functional classes analyzed in this study have important differences in terms of their eligibility criteria. Notably, the F-44 class is designed especially for athletes with lower limb disabilities, usually amputees and individuals with cerebral palsy (www.cpb.org.br). Balance is among the variables with the greatest impact on motor control in sports activities in the standing position (Reina et al., 2022; Sarabia et al., 2021). Although this is a speculative aspect, athletes in such classes are likely to have less capacity to maintain dynamic balance, especially in activities with greater muscle power. To our understanding, this may be contributing to smaller joint dynamic moments, especially in the lower limbs, resulting in shorter range.

In the F-46 class, all athletes had one of their upper limbs fully amputated. Certainly, the choice of a non-rotating throwing technique also contributed to a shorter range, a fact that was confirmed in the entire studied sample. Probably if the athletes performed other types of technical adjustments, such as the horizontal adduction of the arm, instead of throwing evidencing the abduction of this limb, they could significantly improve the performance as it occurs for elite athletes (Leigh and Yu, 2007). A factor that proves this hypothesis is the important differences observed in the current brands of the F-44 and F-46 classes at the world championships and the Paralympics (https://www.paralympic.org/athletics/rankings). It should be noted that the currently best performing athletes apply the throwing technique with a spin, similarly to Olympic throwing athletes.

In F-44 class athletes, an amputation or deficiency in one of the lower limbs generates less body stability at the time of take-off. This can cause other factors influencing range (height and take-off angle) to have a greater impact than take-off speed. This can be observed by the greater dispersion of the disc's take-off speed in these athletes, since the take-off speed determines the discus range when the angle and take-off height remain constant (Frohlich, 1981) and that the forces of the lower limbs

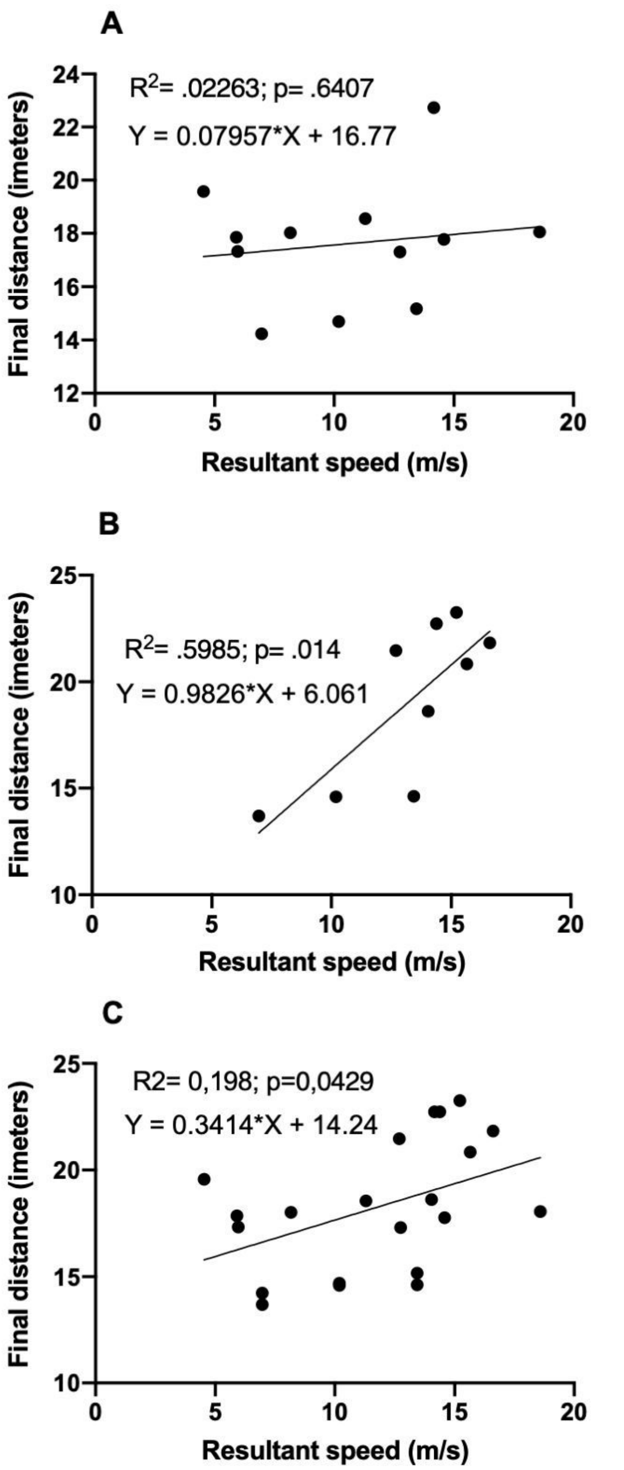

Figure 2. Regression analyses performed between resulting take-off speed and range. Panel A (class F-44); Panel B (class F-46); Panel C (all athletes).

have an important contribution in discus range (Bartlett, 1992; Hubbard, 2008). This would also explain the low correlation values between take-off speed and range in these athletes, which differs in athletes who throw from supports (Bartlett, 1992; Chow and Mindock, 1999), as they have greater stability as they are tied to the support.

The values of functional classification studies (Chow and Mindock, 1999; Frossard et al., 2010) in which a lower class gives lower results than the class immediately above for athletes who throw on supports in classes F-30 and F-50 (Chow and Mindock, 1999; Frossard et al., 2013a, b). However, when looking at current world records, the discus range in the F-46 class is smaller than in the F-44 class, nonetheless, here an inverse situation occurred because of the throwing technique.

Certainly, the absence of an upper limb seems to harm the athlete's balance, making them choose to throw without the turn technique, thus reducing the speed towards the throw, consequently in the take-off speed and range. Thereby, it is suggested for athletes in this class to adopt the turning technique for throwing as a way to improve competition performance.

It is worth highlighting some of the limitations of this study. Initially, the small sample size makes it impossible to extrapolate the results obtained. Still, the reduced number of athletes is in line with the practice of similar previous studies. Another aspect that should be mentioned is the likely lower technical capacity of the assessed athletes. Athletes with little experience usually participate in regional events, which is the case herein. Finally, the last limitation concerns the absence of women in the studied sample.

The main practical implications of the study lie in understanding the technical factors that best contribute to performance in the Paralympic discus throwing event, especially for athletes in the F-44 and F-46 classes. Normally, a more appropriate technique must be acquired in the beginning phase athletes, and then be continuously introduced in training routines. Therefore, aiming to privilege greater dynamic control of the implement, with a special focus on learning and developing the rotational throw technique, the technical improvement will provide the necessary bases for other important performance components to evolve, such as strength training and power muscle.

CONCLUSION

The results pointed to important differences in the associations between take-off speed and range for Paralympic disc throwers of functional classes F-44 and F-46. We believe that the sucess in throwing would be related to better stability of the lower limbs, so that the take-off speed is optimized. Athletes with disabilities who perform disc throwing without the aid of support should adopt the traditional disc (spin) technique since it would be the most coherent alternative for these athletes.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest in publishing the results of this investigation.

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