DOI: 10.4025/jphyseduc.v30i1.3078

Original Article

DROP HEIGHT IS INFLUENCED BY BOX HEIGHT BUT NOT BY INDIVIDUAL STATURE DURING DROP JUMPS

A ALTURA DA QUEDA É INFLUENIADA PELA ALTURA DA CAIXA, MAS NÃO PELA ESTATURA INDIVIDIAUL DURANTE OS SALTOS EM PROFUNDIDADE

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ABSTRACT
Drop jump (DJ) performance an important aspect in many sports. The optimal stretch load in the DJ training is commonly prescribed through the box height from which individuals must drop from. However, studies have reported differences between real (calculated) drop heights and box heights, which may affect the quality of the prescription of DJ training load. Other aspects such as individual stature may also affect the differences between calculated drop heights and box heights. This study aimed to 1) investigate the difference between calculated drop heights and box heights in different box heights and 2) verify the influence of individual stature on the difference between calculated drop heights and box heights. Twenty-two individuals performed DJs from different box heights and landed on a force platform. An ANCOVA was performed to verify the influence of stature and box height on the difference between calculated drop heights and box heights. We found that calculated drop height was different from box height for all box heigths. The difference between calculated drop height and box height significantly increased as box heights increased. Individual stature did not influence the difference between calculated drop heights and box heights. We can concluded that box heights are significantly different from calculated drop heights. These differences increase as the box height increases, i.e. an increase in the difference of approximately 2 cm every 10 cm increase in box height. Therefore, it seems that coaches can use the same procedures for prescribing DJ training load for individuals of different heights
Keywords: Drop height. Drop jump. Plyometric training. Stature.

RESUMO
O desempenho do salto em profundidade (SP) é um aspecto importante em muitos esportes. A carga ideal de treinamento de SP é comumente prescrita através da altura da caixa da qual os indivíduos devem cair. No entanto, estudos relataram diferenças entre alturas de queda reais (calculadas) e alturas de caixas, o que pode afetar a qualidade da prescrição da carga de treinamento de SP. Outros aspectos, como a estatura individual, também podem afetar as diferenças entre as alturas de queda calculadas e as alturas da caixa. Este estudo teve como objetivos 1) investigar a diferença entre alturas de queda calculadas e alturas de caixas em diferentes alturas de caixas e 2) verificar a influência da estatura na diferença entre alturas de queda calculadas e alturas de caixas. Vinte e dois indivíduos realizaram SPs de diferentes alturas de caixa e aterrissaram em uma plataforma de força. A altura calculada de queda foi diferente da altura da caixa para todas as alturas da caixa. A diferença entre a altura de queda calculada e a altura da caixa aumentou significativamente à medida que a altura da caixa aumentou. A estatura individual não influenciou a diferença entre alturas de queda calculadas e alturas de caixas. Podemos concluir que as alturas das caixas são significativamente diferentes das alturas de queda calculadas. Essas diferenças aumentam à medida que a altura da caixa aumenta, isto é, um aumento na diferença de aproximadamente 2 cm a cada 10 cm de aumento na altura da caixa. Portanto, parece que os treinadores podem usar os mesmos procedimentos para prescrever a carga de treinamento de SP para indivíduos de diferentes alturas.
Palavras-chave: Altura da queda. Salto em profundidade. Treinamento pliométrico. Estatura.

Introduction

Vertical jump performance is an important motor skill in many sports, e.g., basketball, volleyball, handball, soccer, gymnastics, and track and field. Vertical jumps are also an important training exercise for muscular and neural adaptations in order to improve strength and power of the lower limbs[1-4]. Various assessment methods using vertical jumps are applied for different aims, such as talent selection[4], load control[5,6], and monitoring postoperative treatment[7]. Jump techniques can be distinguished in squat jump (SJ), countermovement jump

(CMJ), and drop jump (DJ)[8,9]. The SJ allows the assessment of jump performance through primarily concentric muscle actions, while CMJ and DJ include the stretch-shortening cycle (SSC). Whereas the CMJ is characterized by the long SSC (>0.7 s), DJs are performed within contact times less than 0.25 s[10]. In sports that require jumping within short contact times (e.g. volleyball, basketball, long jump, triple jump, high jump, and sprinting), DJ performance is one of the most important motor skills. Therefore, plyometric training by DJs is one of the preferred methods to improve jump performance and leg muscle power[10,11].

The DJ requires the athlete to drop from a box and attempt to perform a maximal jump with a contact time less than 0.25 s. The stretch load during the SSC depends on athlete's mass and the vertical velocity of the Center of Gravity (CG) at the moment of the first ground contact, i.e. landing velocity[8]. Since the mass of the athlete is constant, different box heights lead to different landing velocities and, consequently, different stretch loads during the SSC. The optimal stretch load is individually determined and is supposed to lead either to the highest performance index (jump height/ground contact time) or the greatest jump height[2,3,12]. The optimal stretch load in the DJ training is commonly prescribed through the box height from which individuals must drop from[12,13], which is the box height that leads to the best performance. Therefore, training load prescription commonly considers the drop height equal to box height[12,13]. However, Bobbert, Huijing, and Van Ingen Schenau[14] found lower mean drop heights than box heights for 6 male students who dropped from box heights of 20, 40, and 60 cm. In this study, the real drop height was calculated from the vertical impulse recorded by a force platform (the impulse caused by the vertical ground reaction force). In line with these results, Kibele[15] also found differences between box height and the calculated drop height using the flight time method. These diferences between drop height and box height could affect the prescription of individual plyometric training load of DJs. Therefore, data clarifying the possible factors that influence training load will allow a higher individualization and a better quality of prescription of DJs trainng load.

Differences between box height and drop height may be caused by dropping technique. Bobbert and colleagues[14] reported that individuals tend to take a slightly bent posture before jumping down during the DJs. In addition, they may raise or lower their CG when stepping forward before the drop. Moreover, we do not know whether individual stature can influence these technique aspects. Therefore, it is important to verify whether individual stature may act as a covariate in the difference between box height and drop height. Additionally, if individual stature is shown to impact the difference between box height and drop height, it is important to verify whether this impact is influences by box height. These pieces of information will also add quality to training prescription of DJs. Nevertheless, we did not find any studies on the influence of stature on the difference between distinct box heights and drop height.

Considering that the knowledge about athletes' optimal stretch load is essential for prescribing plyometric training load, as well as monitoring jump performance using DJs, this study aimed to verify the influence of box height and the covariate individual stature on the difference between box height and drop height.

Methods

Participants

Twenty two male physical education students (age: 21.1 ± 2.3 years; stature: 1.77 ± 0.11 m; body mass: 74.2 ± 10.0 kg; body mass index: 23.6±2.1) participated in the study. Their stature, body mass, and body mass index (BMI) are shown in Table 1. All participants were physically active and did not present any orthopedic limitations or lower limbs injuries within the last 6 months. The study was approved by the local Ethics Committee in accordance with international standards (ETIC 34/08). All subjects signed an informed consent.

Procedures

The subjects were already familiarized with the drop jump technique so that special preparation and familiarization was not necessary since Bobbert, Huijing and Van Ingen Schenau[10] found that familiarized subjects are able to perform drop jumps consistently. Following the assessment of stature and mass, participants performed 15 min of individual warm-up exercises, including running at an individually chosen velocity, calisthenics, and drop jumps from a 30 cm box. After warm up, they performed three valid drop jumps for each box height (20, 30, 40, and 50 cm) as recommended by Sale[9]. The sequence of trials from different box heights was randomized and balanced between subjects. The rest interval between trials of the same box height was about 1 min and between different box heights about 2 min.

Participants dropped the boxes and landed on an AMTI OR5-6 force platform, where the ground reaction forces were registered at 1000Hz sampling rate until the individual achieved a stable landing posture without any vertical movement after drop jump landing. The criterion for complete landing was a maximal oscillation of vertical ground reaction force less than 5N for at least 2 seconds after landing. Drop jumps with contact time less than 0.25s and complete landing with the entire feet placed on the force platform were considered valid. The vertical ground reaction forces were collected by DasyLab V8.0 software. In order to calculate the drop height, the force-time curve was integrated and landing velocity (v_L) after dropping from the box was calculated by the impulse-momentum method as described by Baca[16] and Linthorne[17]. The vertical ground reaction force was registered at a frequency of 1 kHz and lowpass filtered at 50 Hz with a fourth-order, zerolag Butterworth filter implemented in the software DASYLab 11.0. The calculated drop height (h) was obtained using the equation $h = v_L^2/2g$ [15]. The mean of the calculated drop heights for the three trials in each box height was calculated for each subject.

Statistical analysis

Descriptive statistics included means and standard deviations for calculated drop heights (h_i) and for the differences between calculated drop height and box height ($\Delta h_i = b_i - h_i$) for all box heights. All variables presented no significant deviations from normal distribution, as verified by the Shapiro-Wilk test. The reliability of calculated drop height was estimated for every box height by the calculation of the intra-class correlation coefficient (ICC) (and confidence interval) and standard error of measurement for the three valid trials in every box height[18]. The ICCs were used to evaluate both systematic and random errors for calculated drop height between DJ trials (test–retest reliability). ICC were classified as weak (<0,4), moderate (0,4 - 0,59), good (0,6 - 0,74), and excellent (0,75 - 1)[19].

Differences between calculated drop heights and box heights for the different box heights were identified using a covariance analysis (ANCOVA) with stature as covariate. This analysis was performed for the mean of the three drop jumps with best performance. All statistical procedures were performed by SPSS V17.0. Statistical significance was set at 0.05.

Results

Descriptive and inferencial statistics of the calculated drop heights and the differences between calculated drop heights and box heights are shown in Table 1.

Table 1. Calculated drop heights and differences between calculated drop height and box height

	Box Height (cm)							
	20		**30**		**40**		**50**	
	M	sd	M	sd	M	sd	M	sd
Calculated Drop Height (cm)	13.7	1.6	21.8	2.1	29.4	2.6	37.5	2.0
Difference between calculated drop height and box height (cm)	6.3	1.6	8.2*	2.1	10.6*	2.6	12.5*	2.0

Note: M = Mean; sd = Standard deviation. * Significant difference compared to the previous box height
Source: authors

The results of the ANCOVA indicated no significant influence of stature on the differences between calculated drop height and box height (F=0.15, p=0,70). There were significantly increasing differences between calculated drop height and box height over the different box heights (F=35.27, p=0.001) (Table 1).

Intraclass correlation coefficients and standard errors of measurement of the calculated drop heights from the four box heights are shown in Table 2. These results indicate excellent reliability for calculated drop height between DJ trials in each box height. The high ICC values and the low SEM values support the understanding that the verified differences between calculated drop height and box height over the different box heights are consistent.

Table 2. Intraclass correlation coefficients (ICC) and standard errors of measurement (SEM) for the calculated drop heights in each box height

Box height	ICC	SEM	ICC classification
20 cm	0.83	0.71	Excellent
30 cm	0.83	0.91	Excellent
40 cm	0.93	0.72	Excellent
50 cm	0.80	1.01	Excellent

Source: Authors

Discussion

The aim of this study was to verify the influence of box height and the covariate individual stature on the difference between calculated drop heights and box heights. Literature has shown that box height is a determinant factor for DJ performance and that there is an optimal box height for power generation during this type of jump[20]. Therefore, training load prescription commonly considers the drop height equal to box height[12,13]. However, we found differences between box height and calculated drop height for all box heights investigated in this study and these differences significantly increased as box height increased. This result corroborates with data of Bobbert Huijing, and Van Ingen Schenau[14], who found a shorter drop height than box height from which the participants stepped down. Bobbert, Huijing, and Van Ingen Schenau[14] suggested that these diferences may be related to the dropping technique, such as increasing knee and hip flexion angles to step down from the box as box height increases. The flexion of these joints decrease the real drop height compared to box height leading to a lower landing velocity and, consequently, a lower calculated drop height. Nevertheless, our hypothesis that the individual stature could influence the difference between calculated drop height and box height was rejected. Therefore, it seems that individual stature does not affect the dropping technique adopted during the DJ nor the changes in the dropping technique as box height increases. However, the experimental design of this study did not include a kinematic analysis of the jumping movement, requiring a further support for confirming this explanation.

Another interesting result of this study regards the impact of increasing box height on the magnitude of the differences between calculated drop height and box height. Our results showed a tendency of ~2 cm larger differences between box height and calculated drop height every 10 cm increase in box height. Therefore, the possible alterations in the dropping technique Bobbert, Huijing, and Van Ingen Schenau[14], seem to be consistent in all box heights.

This study results provide information that may lead to a better understanding of the plyometric training load using DJs and increase the quality of load prescription and monitoring. Future studies should investigate whether the use of feedback related to the dropping technique could decrease the differences between box height and calculated drop height and, consequently, influence jump performance over a period of training using DJs.

As previously mentioned, we hypothesized that individual stature would significantly affect the difference between box height and calculated drop height. However, the ANCOVA analysis did not confirm this hypothesis. The low coefficient of variation (approx. 6%) for individual stature among this study participants may have prevented the finding of a significant effect. Future studies using kinematic analysis of jumping technique and a more heteregoneous group (i.e., a higher range of individual statures) of individuals should confirm this explanation.

Conclusions

We can conclude that box heights are significantly different from calculated drop heights. These differences increase as the box height increases, i.e. an increase in the difference of approximately 2 cm every 10 cm increase in box height. Apparently, individual stature does not affect the difference between calculated drop heights and box height. Therefore, it seems that coaches can use the same procedures for prescribing DJ training load for individuals of different heights.

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Acknowledgments: This study was supported by FAPEMIG (APQ-00220-08). We thank the Brazilian Society of Biomechanics for promoting research in Physical Education and Sport, seeking to strengthen the links between scienctific research and the performance of professionals in the area of exercise and physical training.

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Received on Sep, 18, 2018.
Reviewed on May, 05, 2019.
Accepted on Aug, 20, 2019.

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