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ANALISYS OF HALF-SQUAT MECHANICAL SPECIFICITY TO TRACK AND FIELD THROWING TECHNIQUES

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The aim of this study was to measure and compare the leg kinematics and kinetics of half-squats with a large spectrum of loads and three different track-and-field throwing actions (hammer, discus and javelin throws). One experienced thrower of each discipline was selected. Knee angular velocity, knee angle and vertical ground reaction force were measured for the half-squat and the throwing techniques. The results suggested that this method allows training loads to be selected for the half-squat that are more specific to the individualized performance of each leg.

KEY WORDS: half-squat, specificity, track-and-field, throws, strength, kinetics, kinematics.

INTRODUCTION: In high performance sports, the specificity principle is regarded as the guarantee that the training stimulus acts on the systems directly related with performance (Reilly et al., 2009). Coaches attempt to adapt the classical resistance training exercises to the contraction pattern, range of motion, velocity, force of contraction, muscular fibre recruitment, movement pattern, etc. that are required to maximize performance (Verkhoshansky & Siff, 2009). Some research has been done on the kinetic and kinematic determinants of the track and field throwing performance but there is a lack of studies attempting to precisely determine how mechanically specific can be the most widely used resistance training exercises for these throwing disciplines. The aim of this study was to measure and compare the kinematics and kinetics of the lower limbs during the execution of half-squat with multiple loads and the throwing action of javelin, hammer and discus throws.

METHODS: Three experienced national level throwers (age 21±4; weight 89±25; height 178±3) specialists in hammer, discus and javelin throws participated in this study. Knee angular velocity (KAV), knee angle (KA) and vertical component of the ground reaction force (VGRF) were assessed both in the half-squat exercise and in the throws. To measure these variables in the half-squat exercise we used an electro goniometer (Penny+Gilles), carefully attached to the knee, and a force platform (Bertec 4060-15). These instruments were connected and synchronized by an A/D converterplate (Biopac MP100) and respective software (Acqknoledge 3.9.1), sampling at 1000Hz. To assess KAV and KA during the technical execution, we used a set of four *Quos* infrared cameras (Qualisys – Motion Capture Systems) and a 3D reconstruction software (Qualisys Track Manager 2.0.338). For the VGRF a plantar pressure measurement system, composed by a network of eight sensors attached to the insole of the athlete's shoe was used (Walking Senses, Tomorrow Options Microelectronics). These two systems were sampled at a frequency of 100Hz and manually synchronized. In the first part of the evaluation, the force production of half-squat was assessed, through six different randomly ordered loads, ranging from 20kg to 100% of the RM previously indicated by the athlete. Two valid extra repetitions were performed with the lighter load (20kg) performing a half-squat ballistic jump. By having the velocity feedback and based on the linear velocity-load relation of half-squat described by Sanchez-Medina (2009), we were able to monitor and re-adapt the load if the attempt of RM was under or overestimated. After a briefing on the objectives of the session, a period of 10 minutes warm up and familiarization with the equipment was allowed. The half-squat was executed in a Smith machine (Multipower Fitness Line), with a controlled velocity during the eccentric phase, until the athlete attained approximately 90º knee joint angle. At this instant, an audio signal of the evaluator triggered a maximum commitment concentric phase. The athlete executed two valid trials of each load under 85% of the predicted RM and just one trail with heavier loads. The valid trial from each load, with greater mean propulsive velocity (Sanchez-Medina et al, 2010) was the one selected for further analysis. The recovery time was set in one to two minutes between repetitions and four to six minutes between sets. A second evaluation phase consisted on the assessment of the technical performance of each discipline. An indoor cage was specially built to allow safety during the evaluation and to stop the projectile about 4 m after the release point. Each athlete executed four trials in the discipline of his speciality and the best one, chosen based on the throwing wrist higher velocity, was selected for further treatment.

A preliminary study was conducted to compare the result obtained with the force plate and the plantar pressure system, in order to minimize the limitation of the area motorized by the plantar pressure sensors and the difference inherent to different equipment's.

Data treatment was performed in Matlab (The MathWorksInc, USA). A simple moving average filter was applied to vertical ground reaction force and angle signals. After the calculation of the KAV, a low pass fourth order Butterworth digital filter with cut-off frequency of 10Hz was applied. Data were resampled and interpolated using cubic splines and 3D surface plots were created. Identification and interpolation of trajectories and calculation of knee angular velocity of the kinematic data from the throw techniques was done using the Qualisys Track Manager software (2.0.338). To establish the range of the movement, the data of each leg during the last support phase of the throw was analyzed and compared with the concentric phase (positive angular velocity) of the half-squat data.

RESULTS AND DISCUSSION: The relation KAV-KA-VGRF in the half-squat with multiple loads is presented in the figure 1.

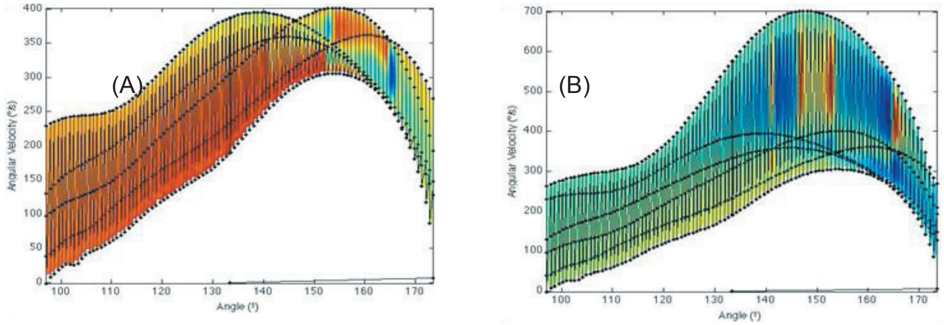

Figure 1: Relation of KAV-KA-VGRF in the execution of half-squat with different loads by the discus thrower. (A) Without a ballistic execution (B) adding a ballistic execution with the lighter load.

The colour grid represents the interpolated VGRF while the dotted lines represent the real data obtained from each load repetition. It can be seen in figure 1 that in the execution of the half-squat the force-velocity follows the classical relationship presented by Hill (1938) in angles smaller than 140 degrees. This linearity enables the load order of the lines to be distinguished: lighter loads with higher starting velocities and heavier loads with the lower starting velocities. Nevertheless, the half-squat done with a concentric execution without ballistic end presents a braking phase that is greater and starts in a sharper angle in lighter loads, in comparison to heavy loads. This causes the loss of linearity evident in the figure and points to the difficulties associated with interpolation at angles wider than 140 degrees. By adding a ballistic execution with the lighter load (figure 1B) the knee angular velocity range of the exercise increases significantly. These results allow a clear view of the implications regarding the mechanical output at different loads and execution patterns.

Figure 2 represents the comparison of the KAV, KA and VGRF of each leg action during the throw techniques with the surface reconstructed with the half-squat data.

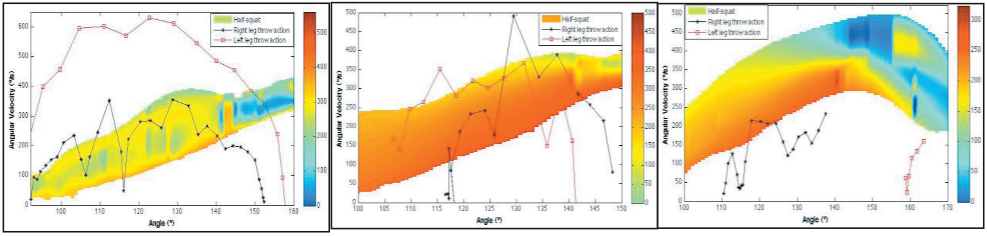
(A) (B) (C)

Figure 1: Comparison of half-squat and technical right (black) and left (red) throwing actionson the relationship between KAV and KA. (A) hammer thrower; (B) discus thrower; (C) javelin thrower.

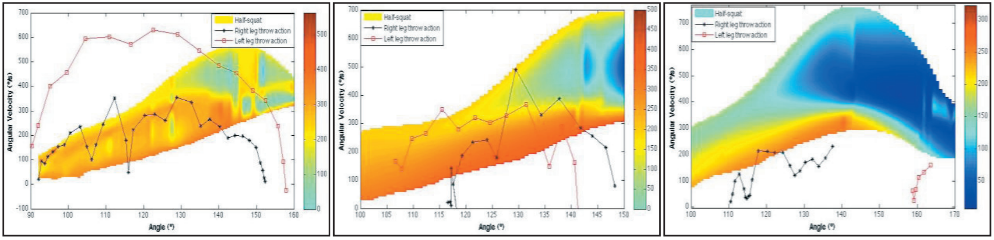
(A) (B) (C)

Figure 2: Comparison of half-squatwith a ballistic lighter load execution and technical right (black) and left (red) throwing actionson the relationship between KAV and KA. (A) hammer thrower; (B) discus thrower; (C) javelin thrower.

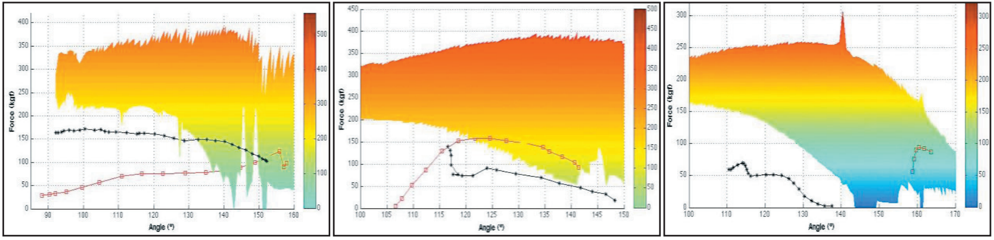
(A) (B) (C)

Figure 3: Comparison of half-squat and technical right (black) and left (red) throwing actionson the relationship between VGRF and KA. (A) hammer thrower; (B) discus thrower; (C) javelin thrower.

For the hammer thrower, the right knee throwing action (RKTA) had good adherence to the pattern of the light load half-squat (figure 2A). Nevertheless the curve pattern of the throwing action is clearly non-linear, unlike the half-squat execution pattern. This fact constitutes a pattern of movement specificity limitation of the half-squat for this athlete. The left knee throwing action (LKTA) of the same athlete revealed a much higher velocity than the maximum velocity of the half-squat (figure 2A), even when a light load ballistic execution is included on the half-squat spectrum (figure 3A). These results suggest that the half-squat executed with the spectrum of loads studied is not specific for the velocity requirements of the LKTA in the hammer throw. However, the ballistic execution of the lighter load improved the association. We speculate that a no-load ballistic execution would improve it further. This significantly bi-lateral difference in the hammer throwing action makes clear that a symmetric exercise like the half-squat may not allow a good level of specificity for both legs simultaneously. Therefore coaches must be aware that, when choosing a half-squat load training zone, they might be giving a non optimal stimulus to either of the legs as the output is the combination of their force production characteristics. When specificity is the focus, we suggest an individualized approach to each leg assessment and strength training.

In the discus throw, both knee throwing actions revealed a good association to the velocity-angle spectrum of the half-squat (figure 2B and 3B). The light loads and the ballistic execution were specific to the LKTA of the discus thrower, at least in an angular range from 110 to 137 degrees. For the RKTA of the discus, relatively heavy loads seemed to relate to the required knee angular velocity of the first phase of the movement until 127 degrees. After this knee angle, the velocity of RKTA increases very quickly being just matched by the half-squat lighter load ballistic execution. These results suggest that the half-squat can be mechanically specific to both legs in the discus throwing action. Nevertheless, different phases of the technical execution relate to different load spectrum zones. In the case of the javelin thrower, the throwing knee action in both legs revealed a slower velocity than that provided by heavy load half-squat. This result might be justified by the prevalence of eccentric contraction on the last support of the javelin throw, allowing only slow concentric contractions. Even so, the expected fast concentric contraction at the end of the right leg action was not evident, probably due to the technical level of the athlete.

CONCLUSION: Our results indicate that the method used in this study can precisely determine the training loads for the half-squat that are more specific to the individualized performance of each leg throwing action and its different phases. We also noticed that the use of symmetrical exercises might not be specific for the action of both legs. The use of single leg exercises or different target loads for the same period of training might allow greater specificity. Since this study was conducted using only a small sample, further data are needed for a deeper comprehension of this relation. However, the data suggest that this method can give valuable individual information for the use of correct training loads and mutual adaptation of strength training exercises and technical gesture.

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