Evolution of the sprint power-strength-velocity profile according to the amplitude used in the ballistic squat in young elite rugby players

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Headline

The choice of squat amplitude is a highly controversial topic that divides strength and conditioning coaches. While some researchers have demonstrated that the full squat induces superior strength development (1,2), others have highlighted the potential risks of this type of squat on the knee joint (3,4). On the other hand, few studies have investigated the effects of ballistic squat training work with reduced amplitudes, such as the half or quarter squat, potentially inducing a better adaptation of the neuromuscular system to produce high levels of speed required for sprinting performance (5,6).

Aim

The aim of the present study was to measure the evolution of the maximum mechanical capacities of the neuromuscular system in sprinting, characterized by the power-force-velocity profile, according to the amplitude used in the ballistic squat.

Athletes

Twenty-one young elite rugby players (mean±SD: age: 16.52±0.75 years, body mass: 78.8±12.33 kg, height: 178.6±7.18 cm) were involved in an elite structure with daily training. All subjects play at the highest national level in their category and had at least one year of experience in gym training, and a good technical control of the squat movement.

Design

The present study was carried out over a period of 10 weeks, including a 2-week break between the initial tests and the start of the experimental protocol, due to a period of school holidays. The aim of the first week was to perform all the tests, then all the subjects completed 2 sessions of ballistic squat training per week for a period of 6 weeks.

Methodology

The subjects first performed a 1/2 squat 1RM strength test to assess their absolute maximal strenght. After a 48-h recovery period, the subjects were asked to perform a 30-m maximal sprint test, in order to determine their individual power-strength-speed profiles. All the sprints were filmed (iPhone 13, Apple Inc., Cupertino, CA, USA) to allow video analysis via the "My Sprint" application, and then an Excel file (Microsoft Excel, Microsoft Corps., Redmond, Washington, USA) was used to determine the profiles. The subjects were also equipped with a 10 Hz GPS (Playertek Pod, Catapult, Melbourne, Australia) to measure their maximal velocity (Vmax in km/h). The subjects were then divided into 3 groups working with different knee flexion angles: Q-SQ (120°), H-SQ (90°), and F-SQ (45°). For 6 weeks of training sessions, consisting of 2 sessions per week, the subjects performed 1 set of 10 repetitions at 50% of 1RM, 1 set of 8 repetitions at 60% of 1RM and 3 sets of 6 repetitions at 70% of 1RM, of ballistic squat. The bar speed of the 3 sets at 70% of 1RM was measured using the FLEX device (Kinetic, Cambera, Australia) for all conditions and throughout the protocol. After 6 weeks, the subjects were tested on 30-m sprint.

Statistics

Statistical analysis was performed using Prism 10 (GraphPad Software, San Diego, CA, USA). Quantitative data are expressed as mean±standard deviation. Normality of the values was tested using the Shapiro-Wilk test ($p<0.05$), and the homogeneity of the variances was tested using the Levene test ($p<0.05$).

Once the conditions were met, the parametric two-way ANOVA test (group and time effect) was used to determine the significance of each training condition (Q-SQ, H-SQ and F-SQ). A one-way ANOVA was used to compared bar speeds between groups. The significance level was set at $p<0.05$.

To measure the magnitude of the effect of each condition, the effect size was calculated using Cohen J. (1988). Statistical Power Analysis for the Behavioral Sciences. New York, NY: Routledge Academic and is presented for all variables as negligible (< 0.2); small (0.2–0.5); moderate (0.5–0.8); large (0.8–1.2); very large (1.2–2.0); and huge (>2.0).

Results

The average bar speed during the training session was lower in the F-SQ group compared to the other groups ($p<0.001$, respectively: 0.84 SD ± 0.11 for Q-SQ, 0.80 SD ± 0.06 for H-SQ and 0.62 SD ± 0.07 for F-S).

Two-way ANOVA showed a significant improvement in Vmax (in km/h) for all conditions (****$p<0.0001$), with a larger effect size for F-SQ than Q-SQ and H-SQ (respectively, ES=1.27, 0.74, 0.83). There was also a significant improvement in V0 (in m/s) for all conditions with a greater effect size for F-SQ than Q-SQ and H-SQ (respectively, ES=1.26, 0.53, 0.81) (*$p<0.05$). Pmax (in W/kg) was also significantly increased for all conditions with moderate to large effect sizes (ES=0.82, 0.84, 0.59 respectively for Q-SQ, H-SQ, F-SQ, *$p<0.05$). Finally, there was no significant improvement in F0 (in N/kg), with even a trivial decrease observed for F-SQ (-2.63%, ES=0,22) and Q-SQ (-1.44%, ES=0,10).

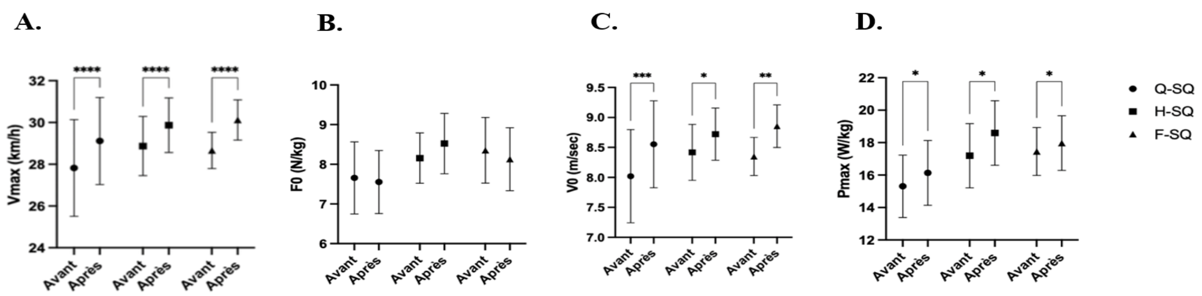

Fig. 1. Sprint performance and sprint Power–Force–Velocity profil parameters: (A) Vmax: maximum speed (B), F0: Theorical Maximum Force, (C) V0: theorical maximum velocity, (D) Pmax : maximum power. *p $<$ 0.05, **p $<$ 0.01, ***p $<$ 0.001, ****p $<$ 0.0001.

Discussion

The results obtained in this study showed a significant improvement in Vmax (km/h) for all the training conditions, with a larger effect size for the F-SQ group compared to the other conditions. This is consistent with previous studies showing the effectiveness of squat work in the development of sprint performance (6,7).

The present study highlighted the interest of using ballistic squat in order to optimize the production of speed during the movement, and thus get closer to the power-strength work zone for the H-SQ and F-SQ groups, and power-speed for the Q-SQ group.

A significant improvement in Pmax and V0 was observed in all the groups, suggesting that ballistic training, represented by a concentric phase performed at maximal speed, with loads of between 30 and 60% of 1RM, led to higher speeds of movement, and thus stimulated a high-speed adaptation of the muscle enabling it to approach the speeds of movement specific to sprinting (8). The bar speed measurements with the FLEX device showed that loads at 70% of 1RM, performed as a 1/4 squat, made it possible to work in a power-velocity zone.

However, the results did not show any effect of training on F0 (in N/kg), particularly for the Q-SQ (-1.44%, ES=0.10) and F-SQ (-2.63%, ES=0.22) groups. Only the H-SQ group exhibit a moderate increase of F0 (+4.41%, ES=0.52) in sprint power-strength-velocity profile, potentially meaning a better transfer of force production capacities when the squat is performed at 90° of knee flexion, which could explain the researchers' choice to use the 1/2 squat.

Practical Applications

The results obtained in this study suggest that ballistic squat training appears to be an effective method for developing sprint performance, particularly in improving the ability to produce maximal speed. On the other hand, it does not influence the production of maximal strength. Finally, although no significant difference has been established between the improvement in maximum speed performance and the amplitude used during the ballistic squat, it seems that the more the muscle is stimulated to produce high contraction speeds, the more there will be an adaptation in the speed of muscular contraction.

Limitations

- The protocol was performed during a competition period, which means that the subjects performed field trainings. Therefore, we could not rule out an interaction effect of the other training sessions even if the training session was similar for all the groups.
- There was also a significant increase in ambient temperature between the evaluation periods (+13°C), with a cold environment during the initial tests having a detrimental effect on sprint performance, and a warmer environment at the end of the protocol having a beneficial effect (9).

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