From the Field: Case Study

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Title

Comparison of the Eccentric Overload metric in the kBox, Trap Bar Jump Squat and Back Squat.

Abstract

Research has identified the importance of eccentric strength training in injury prevention and sports performance. Therefore, the purpose of this Case Study is to profile and compare the Eccentric Overload metric of the kBox, Back Squat and Trap Bar Jump Squat. Two Professional Rugby League players were analysed as case studies (mean training age = 10 ± 1 year). Across the course of the season both athletes performed the kBox Squat, Back Squat and the Trap Bar Jump Squat and were compared to the rest of the playing squad. Eccentric Overload was chosen to compare exercises and calculated by dividing the Eccentric Peak Power by Concentric Peak Power obtained with different technologies. The Back Squat generated much less Eccentric Overload (mean = -36 ± 7) when compared to the kBox (-6.48 ± 7.51) and Trap Bar Jump Squat (1.04 ± 0.02). These findings highlight the value of measuring Eccentric Overload and may have practical applications for Coaches in the Periodization of strength exercises in preparation for eccentric and deceleration forces associated with sports and injuries.

Key Words: Eccentric Overload, kBox, Back Squat, Trap Bar Jump Squat.

INTRODUCTION

Strength training and analysis for sports that largely focuses on performance-based metrics subsequently results in concentric biased training methods (20, 13). However, many sporting actions and associated injuries have an eccentric component (17) and often occur in a reactive environment

(10). The principle of specificity (15), therefore suggests, it would be necessary to perform specific strength training with eccentric and reactive components in order to stimulate the required adaptations to reduce injuries and improve sports performance.

Eccentric training is an effective method to prevent injury of specific muscles such as the hamstrings (11). De Hoyo et. al. 2015 (2) demonstrated in junior elite soccer players that a 10-week eccentric overload strength program consisting of half squat and leg curl, with flywheel technology, resulted in a substantial enhancement (Effect Size 0.59 versus -0.34) in the improvement in injury severity (number of training or match days absent per injury). Additionally, this program also showed improvements in common soccer tasks of jumping and linear sprint speed.

The objective of high-speed deceleration in running is to decrease the body's momentum via the application of as much force as possible over minimal time (10), Therefore, the rapid application of high amounts of braking forces in short Ground Contact Times is important (3). Harper et. al. (9) demonstrated that knee extensor eccentric strength performed in an isokinetic dynamometer at 60 degrees per second, had correlations (Pearson's correlation coefficients (r) of -0.63 in the dominant leg and -0.54 in the non-dominant leg. The authors, therefore, qualitatively inferred very likely large correlations with deceleration ability from high sprint velocities in a linear sprint and time to stop test. However, of note, in this study was the method and speed of testing appearing less specific than required in running deceleration.

Spiteri et. al. 2014 (20) demonstrated that out of a range of measures, eccentric strength had the highest overall contribution (25.34%) to Change of Direction (COD) tests (T-Test and 5-0-5 COD test). Out of the strength measures chosen, maximal dynamic back squat, isometric mid-thigh pull, eccentric and concentric only back squat, the eccentric half squat with a 3 second cadence had a significant negative correlation (Pearson product-moments correlation) of -0.87 to -0.89 with the two COD tests. The authors concluded that eccentric strength was identified as the strongest predictor and deterministic factor in COD, but not agility performance with elite female basketball athletes, thus highlighting the importance of the training these qualities to improve COD performance.

With eccentric sporting actions and injuries likely occurring at much higher velocities than replicable with traditional strength training exercises, there exists a large discrepancy between velocities. Therefore, in terms of solving this problem of finding strength exercises and technologies with faster velocities of eccentric contractions and subsequent greater force, power and eccentric overload, exercises such as Squat Jumps and flywheel technology may provide viable options (12, 16). However, what is often not reported in exercises such as the Squat Jump, is the force, velocity and power of the associated Eccentric contractions (19).

Faster movement speeds, impact and ground reaction forces upon landing from jumps, provide a valuable stimulus, not just for contractile tissue, but for bone (6, 18), tendon (5) and muscle tendon system (14). However, children for example, appear to attenuate greater impact forces when jumping from increased heights (drop jumps up to 50cm), thus increasing the height of jumps as a method of progressing the exercise cannot be assumed (18). Therefore, loaded jumps, may be of interest to increase such forces on the musculoskeletal system.

The Trap Bar Squat Jump appears to be a relatively recent exercise when compared to the long history of the back squat. An inherently Velocity Based exercise, the lift exposes the athlete to a range of loads that can be accelerated through the lifts full range of motion. A valid performance-based exercise that is significantly related to jump and acceleration performance in rugby union players (21), upon landing, can provide faster eccentric contractions.

Flywheel technology from Exxentric (Bromma, Sweden), which included the kBox combined with the kMeter, are able to overload eccentric actions while simultaneously measuring force and speed. This has allowed the manufacturers to develop a metric termed Eccentric Overload (EO), which is calculated by dividing the Eccentric Peak Power (Watts) values by the Concentric Peak Power (Watts) (7). This number demonstrates the ability of the subject to decelerate the inertia of the flywheel in the eccentric phase. When applying this metric to selected lifts, a valuable profile can emerge.

Additional to Eccentric Overload, the kBox provides the benefit of a reactive stimuli. With flywheel technology working via inertia and momentum of the flywheel rather than gravity, the mechanism generates subjective reporting that the kBox feels different than any other means of strength training, thus providing an unplanned component to the exercise. Much strength training methods are ‘pre-planned’, allowing the body to setup and pre-tense for optimal force production and reduction. However, with the highly unpredictable, reactive multiplanar nature of sports, the flywheel provides a reactive component to eccentric force production, for a more specific stimulus.

At the point in time of writing, the kBox and flywheel technologies are more expensive than traditional lifting equipment. Therefore, other means and methods must be sourced in order to develop eccentric forces necessary to aid deceleration to prevent/reduce injuries. Thus, the purpose of this article is to compare and report the Eccentric Overload values from the traditional Back Squat, Trap Bar Squat Jump and the kBox.

METHODS

Approach to the Problem

In the context of a professional Rugby League season, an individualised strength program was developed. Initially, screening was used to determine athlete’s competence in the Back Squat. Those not obtaining the optimal mobility for the Back Squat, were selected to perform Trap Bar Squat. With strength training periodisation, Back Squat progressed to a Trap Bar Squat (Squat pattern not Deadlift pattern), then Trap Bar Squat Jump. Additionally, athletes with shoulder and back issues combined and the natural flow of the season and associated ‘football’ injuries, (such as athletes not being able to put a bar on their back or shoulders), the kBox was used as a solution. Two athletes that performed the Back Squat, Trap Bar Jump Squat and kBox exercises during their training prescription, at different time points across the season were selected as Case Studies to compare and profile the Eccentric Overload metric.

Subjects

Two Case study participants from the National Rugby League squad were selected (table 1).

Table 1. Subject characteristics

	Age (years)	Height (cm)	Body mass (kg)	Professional Training Age (years)	Est. 1RM Pause Back Squat (kg)	Est. 1RM Trap Bar Squat (kg)
Subject 1	28	187	100.3	11	142	198
Subject 2	26	182	99.6	9	120	165

*Est. 1RM = Estimated 1 Repetition Maximum best values obtained from corresponding pre-season. cycles.

*Age = chronological age.

*Professional Training Age = years in a full-time professional program.

Procedures

kBox Squats. This equipment was introduced as a new technology and training stimulus, therefore commenced and progressed conservatively. Squats on the kBox were performed via thoracic harness at flywheel loads of 0.05 and 0.075kgm^2 Inertia. In order to generate as much power as possible, as described in the kMeter manual, athletes perform ‘pre-reps’ to generate momentum of the flywheel, before performing their specified repetitions. Because of the reactive nature of this stimuli, athletes react to the eccentric pull of the flywheel and inherently find self-selected depths in order to generate as much power as possible.

kBox clip.mov

Figure 1. kBox Squat

The Eccentric Overload metric, when positive, means that the subject has decelerated the inertia of the flywheel in a shorter time than the time of acceleration/concentric phase, thus generating more eccentric power and creating greater eccentric overload. The more negative the Eccentric Overload, the flywheel has been decelerated in a longer time than the acceleration phase (8) thus generating less Eccentric Overload.

Pause Back Squats. Squats were performed as close as possible to a 'thighs parallel' squat, where a 2 second pause was encouraged before forming the concentric movement with a Velocity Based Training focus (explosive as possible) at greater the 0.7 meters per second. Depth and velocity were monitored via the GymAware technology. Loads recorded for the selected athletes at the point in time were progressed within the session to 80% to 85% of 1 Repetition Maximum for 3 repetitions with repetitions in reserve to in order obtain required velocities.

Trap Bar Squat Jump. A high handled Trap Bar Squat Jump was performed from the ground with traditional sized bumper plates and performed as singular repetitions (3 separated reps), each commencing from the ground. On landing, participants were instructed to return to the starting position as quick as possible, absorbing the eccentric forces through range of motion, without bouncing the bumper plates on the ground. Athletes would then gently return to the starting position of resting the bumper plates on the ground and repeat another repetition. The exercise was introduced as a new lift, therefore progressed from the minimal load of the bar (33.5kg) and progressed linearly across a cycle, up to a maximum of 30kg load on the bar (Total bar weight of 63.5kg).

Figure 2. Trap Bar Jump Squat

Strength Training Program. Strength training was performed 1-2 hours post field training and in both the pre-season and in-season phases (table 2). Lower body sessions involved the following threads of exercises in addition to the Squat pattern exercises; 1) Olympic lifts, 2) Prowler or Resisted Sled Drag, 3) Single Leg Back Extension, Romanian Deadlift or Hip Thrust, 4) Nordics, 5) Lateral Push and 6) Step-Up. Of the Squat pattern exercises, Back Squat, Trap Bar Squat, Trap Bar Jump Squat and kBox, typically 4-5 sets, of progressing intensity were performed.

Table 2. Typical weekly training schedule during pre-season and in-season phases.

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Pre-season	Field-Speed + football drills. Lunch Gym-Upper.	Field-Conditioning + football drills. Lunch Gym-Lower (Bilateral focus).	Recovery.	Field-Speed + football drills Lunch Gym-Upper	Field-Conditioning + football drills Lunch Gym-Lower (Unilateral focus).	Field-Contact session.	Off.
In-Season	Recovery.	Field-Football session. Lunch Gym-Total Body Strength.	Off.	Field-Football session. Lunch Gym-Total Body Power.	Field-Captains Run.	Game.	Off.

*In-season training days dependant on fixtures. Typical Saturday to Saturday game schedule presented.

*Upper = Upper body. Lower = Lower body. Total Body Strength = combined upper and lower body strength exercises. Total Body Power = Total Body Power exercises.

*Recovery = structured or own individual recovery sessions. Off = Day off

Technology. Contemporary strength science technologies such as GymAware (Kinetic Performance, Mitchell, Australia) and kMeter (Exxentric, Bromma, Sweden) allowed the analysis of the Eccentric and Concentric phases of movement separately during specific exercises. GymAware, a Linear Position Transducer after entering body mass and load lifted, only reports the following eccentric metrics: a) Eccentric minimum velocity, b) Eccentric Peak Force (Newtons), c) Eccentric Peak Power (Watts) and d) Eccentric Peak Velocity (m/s). For eccentric analysis the kMeter, without accounting for body mass, reports Eccentric Max Power and the Eccentric Overload metric. Therefore, in order to calculate and compare the EO (Eccentric Peak Power/Concentric Peak Power) in the Trap Bar Jump Squat and Back Squat, Eccentric and Concentric Max Power were used.

RESULTS

For the kBox Squat, subject 1, on average obtained higher Eccentric Overload values, 103% of Concentric values (table 3). Subject 2 on the other hand obtained Eccentric Overload values that were more negative (86%, 14% less Eccentric than Concentric values). When compared to the 9 other players who performed kBox squats during the window of data collection during the season, the two subjects sat at either end of the range of Eccentric Overload values, with the ‘All athletes’ group average of -2.0 or Eccentric values 98% of Concentric values.

Table 3. *Summary of the average Concentric and Eccentric Max Power, Eccentric Overload and Eccentric Peak Power as a percentage of Concentric Peak Power, of all kBox Squat sets recorded via kMeter for Subject 1, 2 and all athletes (n=9) at 0.05 and 0.075kgm*^{2} *Inertia.*

Subject	Lift	Concentric Max Power (W)	Eccentric Max Power (W)	Eccentric. Overload	Eccentric: Concentric %
Subject 1	kBox Squat	1438	1480	1.03	103%
Subject 2	kBox Squat	1160	998	-14.00	86%
All athletes/All reps	kBox Squat	958 ± 539	941 ± 546	-2.0 ± 16	98%

The Back Squat exercise, on average, produced an Eccentric Overload of -27, Eccentric values therefore constituting 73% of the Concentric values for the all squad/all reps group. For subject 1, this value was as low as -43 (57%) and up to -29 (71%) for subject 2.

Table 4*. Summary of subject and squad, average data for all Gym Aware Back Squat repetitions. Concentric and Eccentric Peak Power variables, Eccentric Overload calculation and Eccentric Peak Power as a percentage of Concentric Peak Power.*

Subject	Lift	Concentric Peak Power (W)	Eccentric Peak Power (W)	Eccentric Overload	Eccentric: Concentric %
Subject 1	Back Squat	2555	1456	-43.00	57%
Subject 2	Back Squat	3272	2323	-29.00	71%
All Squad/All reps	Back Squat	3005 ± 863	2209 ± 702	-27.00	73%

W = Watts

Trap Bar Squat Jumping, resulted in Subjects 1, 2 and all athletes recording positive Eccentric Overload values, with Eccentric Peak Power values in the range of 2%-7% greater than Concentric values (table 5).

***Table 5**. Summary of subject and squad average data for all Gym Aware Trap Bar Squat Jump repetitions. Concentric and Eccentric Max Power variables, Eccentric Overload calculation and Eccentric Peak Power as a percentage of Concentric Peak Power.*

Subject	**Lift**	**Concentric Peal Power (W)**	**Eccentric Peak Power (W)**	**Eccentric Overload**	**Eccentric: Concentric %**
Subject 1	Trap Bar Squat Jump	7415	7609	1.02	102%
Subject 2	Trap Bar Squat Jump	6324	6821	1.07	107%
All Squad/All reps	Trap Bar Squat Jump	8568 ± 2159	9053 ± 2651	1.05	105%

W = Watts

DISCUSSION

This case study sought to compare to Eccentric Overload metric between the kBox, Back Squat and Trap Bar Jump Squat, with different technologies. The traditional Back Squat exercise has long been thought of as a high force activity, mainly pertaining to the ability to handle large masses. However, due to the physiological and neural characteristics of stronger eccentric contractions (4), the eccentric load and contraction in the Back Squat is limited by the capacity of the Concentric phase, thus becomes submaximal (1). These findings demonstrate that the Eccentric Overload in Back Squat at loads of 80-85% 1RM are submaximal (mean EO = -36 ± 7), therefore the exercise may be considered a concentrically biased exercise. When profiled against the Trap Bar Squat Jump, both subjects, provided a positive EO (mean = 1.04 ± 0.02). The kBox, provided a high level of EO, with more variability, mean EO = -6.485 ± 7.51), this may be due to the unplanned reactive nature of the device.

Limitations exist in using the EO metric to profile strength exercises in this Case Study. Jump and non-jump exercises were assessed via different technologies i.e. the Back Squat and Trap Bar lifts were assessed via GymAware and kBox assessed via the kMeter. The different software's, recording mechanisms, calculations and filtering present as limitations to this comparison. However, the available metrics between technologies allowed calculation of the EO metric.

Absolute values need also need considered in conjunction with EO. Subject 1 for example, the Trap Bar Jump Squat elicited eccentric max power values approximately 5 times greater than that of the kBox and Back Squat, however, body mass is not accounted for in the kMeter as is with GymAware. For Subject 2 the Trap Bar Jump Squat, Eccentric Max Power was 6.8 times greater than the kBox and 2.9 times greater than the Back Squat. Comparing the absolute eccentric max power between the Back Squat and Trap Bar Jump Squat, the latter provided a much greater stimuli in this area.

In preparation for the decelerations and eccentric actions associated with sporting movements and injuries, the EO values may have important implications for the strength periodization. With a lower EO profile, the Back Squat, may be better situated early in the Periodized strength plan, providing concentrically biased strength development. The Trap Bar Squat Jump, providing a positive Eccentric Overload (eccentric forces greater than concentric forces), may be better positioned later in the Periodized strength plan and closer to the competition period. For a very specific Eccentric Overload strength stimuli of reactive and unplanned nature, the kBox may be well suited to a pre-competition period cycle of training.

PRACTICAL APPLICATIONS

This article highlights the value of measuring the Eccentric Overload (EO) of strength exercises and using the information in conjunction with absolute forces to Periodize strength exercises. When considering the preparation of various tissues in the body for deceleration and eccentric forces associated with sports, the kBox and its reactive nature may be the most specific strength stimuli available. However, the Trap Bar Jump Squat, provides a similar EO profile to that of the kBox, while the Back Squat elicits much less stimuli in the area, therefore may be better positioned early in the Periodized strength plan.

With EO devices such as the kBox less readily available to sub elite and amateur sport settings, the Trap Bar Squat Jump can provide an alternative solution, eliciting important Eccentric Overload and high absolute forces necessary for tissue preparation, injury prevention and concentric force/power production required for sports performance.

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