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Strength & Power

Rest Redistribution Functions as a Free and Ad-Hoc Equivalent to Commonly Used Velocity-Based Training Thresholds During Clean Pulls at Different Loads

by

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This study determined whether redistributing total rest time into shorter, but more frequent rest periods could maintain velocity and power output during 3 traditional sets of 6 clean pulls using 80% (TS80), 100% (TS100) and 120% (TS120) of power clean 1RM with 180 seconds of inter-set rest and during 3 "rest redistribution" protocols of 9 sets of 2 clean pulls using 80% (RR80), 100% (RR100) and 120% (RR120) of power clean 1RM with 45 seconds of inter-set rest. The total number of repetitions performed above 10 and 20% velocity loss thresholds, mean and peak velocity maintenance (the average of all 18 repetitions relative to the best repetition; MVM, PVM), and decline (the worst repetition relative to the best repetition; MVD, PVD) were calculated. For MVM, PVM, MVD, and PVD, there were small-to-moderate effect sizes in favour of RR80 and RR100, but large effects favouring RR120, compared to their respective TS protocols. The number of repetitions within a 20% velocity loss threshold was 17.7 ± 0.6 during RR and 16.5 ± 2.4 during TS (effect size 0.69); and the number of repetitions within a 10% velocity loss threshold was about 13.1 ± 3.7 during RR and 10.7 ± 3.6 during TS (effect size 0.66). Therefore, RR generally allowed for a better overall maintenance of velocity and power, especially at heavy loads. Coaches who wish to implement velocity-based training, but who do not wish to purchase or use the associated equipment, may consider rest-redistribution to encourage similar training stimuli.

Key words: *power, cluster sets, fatigue, weightlifting, resistance training, traditional sets.*

Introduction

Lower body power is considered to be essential for an athlete's overall performance in sports that require triple extension movements of the hip, knee, and ankle (Suchomel et al., 2015, 2017). Therefore, practitioners often implement triple extension movements like weightlifting movements and their derivatives during training. Typically, some training periods may involve high volumes of fatiguing resistance training (RT) in order to elicit greater training adaptations. However, performing multiple repetitions with maximal concentric effort (i.e. traditional sets) exacerbates fatigue (Tufano et al., 2017a), which causes acute decreases in movement velocity and power output. Therefore, some coaches now aim to objectively monitor movement velocity and power output during RT in order to adjust acute training loads or volume to match acute performance with their desired training goals.

Thanks to technological advancements, objective measurements of real-time velocity data have led to the emergence of velocity-based training (VBT). In science and in practice, the foundation of VBT lies in certain velocity thresholds that are implemented whereby exercise is truncated when velocity decreases to a certain degree (González-Badillo et al., 2017; Jovanović and Flanagan, 2014; Pareja-Blanco et al., 2017a; Sanchez-Medina and González-Badillo, 2011). The theory behind this is that all repetitions

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performed are "quality" repetitions, and acute fatigue is mitigated. Generally, research has shown that implementing stricter velocity loss thresholds can result in similar or greater strength and power training adaptations as opposed to more permissive thresholds (Pareja-Blanco et al., 2014, 2017a, 2017b). Despite such promising evidence supporting VBT, some coaches may not implement VBT due to its heavy reliance on expensive technology and the fact that technology can fail unexpectedly. Therefore, cheaper, ad-hoc approaches to preserve movement velocity during RT could be very beneficial.

Without decreasing training loads or training volume, likely the simplest and most effective way to mitigate acute fatigue is to adjust rest periods: specifically, adding intra-set rest. Although the addition of intra-set rest usually serves its purpose, these so-called "cluster sets" might not always be feasible from a practical perspective since they extend total time (Tufano et al., 2016). One alternative to such lengthy cluster set structures is to redistribute the total rest time of traditional set structures to include shorter and more frequent rest intervals (Tufano et al., 2017b). This strategy, known as rest redistribution, can sufficiently maintain velocity and power output within individual sets compared to traditional sets (Joy et al., 2013; Oliver et al., 2016). Moreover, one study (Tufano et al., 2017b) showed that 12-s inter-repetition rest periods allowed for 36 consecutive back squat repetitions to be performed with 75% 1RM without dropping below a 20% velocity-decrease threshold, which is a common threshold suggested by previous VBT researchers in order to elicit maximal power training adaptations (Padulo et al., 2012; Pareja-Blanco et al., 2017a). However, more recent research (Tufano et al., 2018) has shed light on the idea that when using VBT, firm velocity-loss thresholds do not allow for leeway, meaning the training set or an exercise is terminated once athletes' velocity drops below the predetermined velocity threshold.

Therefore, if an athlete has a single "bad repetition", the VBT threshold informs the coach that the athlete should cease the set, whereas in reality, it is possible that the next repetition (or few repetitions) could still be performed above the threshold. This could be problematic as training volume would be incorrectly and inadvertently reduced beyond what is desired. This type of a real-life scenario introduces the idea that although the force-velocity relationship is linear, the "repetition-velocity" relationship might not always be linear in practice. Thus, the current VBT methodology may not be optimal, as VBT assumes that the best repetitions occur at the beginning of a set or a training session and successive repetitions decrease linearly.

With these points in mind, it would be advantageous if a free ad-hoc VBT alternative could treat the resistance training session holistically, rather than on a rep-by-rep basis. Therefore, the purpose of this study was to determine the ability of rest redistribution to maintain velocity and power output during the clean pull exercise, possibly allowing rest redistribution to serve as a free and ad-hoc alternative to VBT. Based on previous findings (Tufano et al., 2017b), we hypothesized that shorter, but more frequent rest periods would allow for greater preservation of movement velocity and power output, and a greater number of repetitions being performed above adopted thresholds when compared to traditional sets.

Methods

Participants

Fifteen strength-trained men participated in this study (age 28.8 ± 4.48, body mass 89.1 ± 8.7 kg), had at least 1 year of resistance training experience using the power clean and the clean pull exercises, and could power clean at least 90% of their body mass. Participants were excluded if they reported any recent musculoskeletal injuries or were not proficient with either exercise technique. Participants averaged a power clean 1-repetition maximum (1RM) of 99.8 ± 10.8 kg, resulting in a 1RM-to-body-mass ratio of 1.13 ± 0.14. All participants were members of a local gym where Olympic weightlifting movements were commonplace during training, which were always supervised by one of the gym's certified coaches. All procedures were carried out in accordance with the Declaration of Helsinki and all participants gave written informed consent prior to the beginning of the study.

Study Design

Participants reported to the lab for a 1RM power clean session and six experimental sessions, which occurred in counter-balanced, randomized order. These experimental sessions included the clean pull exercise for one of the following protocols: 3 traditional sets of 6 clean pulls using 80% (TS80), 100% (TS100) and 120% (TS120) of power clean 1RM with 180 seconds of inter-set rest; and 3 "rest redistribution" protocols of 9 sets of 2 clean pulls using 80% (RR80), 100% (RR100) and 120% (RR120) of power clean 1RM with 45 seconds of inter-set rest (Figure 1). These six experimental sessions were each performed on different days, separated by 48 to 72 hours. For the duration of the study, participants were instructed to refrain from any type of fatiguing lower body activity for at least 48 hours before each session. All participants were allowed to use weightlifting chalk, but lifting belts and straps were forbidden. All participants successfully completed all 18 repetitions in every experimental session.

Repetition-Maximum Testing: Session 1

Participants refrained from strenuous exercise at least 72 hours before Session 1. During Session 1, participant's body height and mass were recorded, and they were familiarized with the protocols and the 0-10 OMNI-RES scale: a resistance training specific rating of perceived exertion (RPE) scale. After a dynamic warm-up with a special focus on the hips, shoulders, and wrists (8 to 10 min), participants performed 10 barbell front squats followed by 3 power clean repetitions at 50%, 2 power clean repetitions at 70%, and 1 power clean repetition at both 80% and 90% of their estimated power clean 1RM, respectively. Power clean 1RM was then assessed starting at 90% estimated 1RM with 2 to 3 min of rest between each successive attempt. The load was progressively increased until the 1RM was achieved. If the participant failed an attempt with an increased load, they were given the option to attempt it a second time. However, no decreases in the load were allowed and if the lift was missed on the second occasion, the load of the last successful attempt was recorded as the 1RM. All participants obtained their actual 1RM in up to 4 maximal trials. Proper technique of the power clean was assessed as discussed previously (Garhammer, 1984; Winchester et al., 2005) by the research personnel (certified weightlifting coaches).

Experimental Testing: Sessions 2-7

During these randomized sessions, the participants performed the clean pull exercise in both traditional and rest redistribution protocols with loads that were based upon their power clean 1RM. The warm-up consisted of the same dynamic warm-up as Session 1, after which the participants performed a set of 5, 4, 3, 2 and 1 repetition at 50, 60, 70, 80 and 90% of the actual load that they had to perform that day (i.e. 80, 100 or 120% of their 1RM power clean), respectively. Therefore, the loads during the warm-ups were not identical across sessions, but instead were standardized according to the load that was to be used during each respective session. A schematic view of the described set structures and their respective loads can be seen in Figure 1.

As all of the participants were well-versed in the clean pull exercise, no specific instructions were warranted for all participants other than standard verbal coaching cues. For example, when appropriate, participants were instructed to avoid initiating the first pull (of the floor) too forward on the balls of the feet and toes, and to maintain the angle of the torso to the floor. In the event that a lifter failed to keep the bar close to the body while transitioning the bar from the knee to the power position, the lifter was reminded to always pull "up and into the body" keeping the bar as close to the body as possible (DeWeese et al., 2012). All participants were instructed to execute triple extension of the hips, knees, and ankles aggressively and as fast as possible, with strong verbal encouragement provided throughout all trials.

During the experimental sets, participants were required to avoid bouncing the loaded barbell off the floor when transitioning from one repetition to the next by implementing a 1-s pause with the barbell on the floor, starting each consecutive repetition with their original setup as determined by the investigators for a repetition to be considered successful. However, there were no repetitions that the investigators deemed unsuccessful, indicating that the experienced participants maintained their clean pull technique and the 1-s pause throughout the entire experiment. During all repetitions, the feet were required to maintain contact with the floor (i.e. no jumping) while allowing the trajectory phase of the lift to reach its maximal height at the conclusion of each repetition to ensure full extension of the ankle, knee and hip joint. The position of the toes and heels were based upon chalk drawings for each participant during all sessions and the distance was measured between the feet to ensure the identical starting stance each time. Ten minutes after completing each protocol, participants were asked to rate their session on a 0-10 RPE scale.

Data Acquisition and Preparation

For the purposes of the present study, a Gymaware (GymAware Power Tool, Kinetic Performance Technologies, Canberra, Australia) linear position transducer device was used to measure mean force (MF), peak force (PF), mean concentric velocity (MV), peak concentric velocity (PV), mean power output (MP), and peak power output (PP) during all repetitions throughout the sessions. The device consists of a power tool, made up of a steel cable that is wound on a cylindrical spool coupled to the shaft of an optical encoder. The power tool unit was placed on the right side of the barbell, between the hands and the loaded sleeves, according to the manufacturer's instructions. The end of the cable was vertically attached to the barbell using a Velcro strap. Gymaware measures vertical displacement of its cable in response to changes in the barbell position. Within the Gymaware software, the displacement data were time-stamped at 20 millisecond time points and down-sampled to 50 Hz for analysis. The sampled data were not filtered. Instantaneous velocity was determined as change in the barbell position with respect to time, which was also directly measured in the Gymaware software. Acceleration data were automatically calculated as change in barbell velocity over change in time for each consecutive data point. The device's software also determined instantaneous force by multiplying the system mass with acceleration, in which system mass was the barbell load plus the relative body mass of the participant (Banyard et al., 2017; Orange et al., 2018). Power was then calculated as the product of force and velocity. Data obtained from the Gymaware were transmitted via Bluetooth to a tablet (iPad, Apple Inc., California, USA) using the GymAware v2.4.1 app, and to the Gymaware online cloud before being exported to Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA) and prepared for further analysis. The device did not require to be calibrated. Similar to previous research (Jukic and Tufano, 2019; Tufano et al., 2016), the effect of set structure on MV, PV, MP, and PP across each protocol was determined by a percent decline from the fastest$_{(max)}$ to the slowest$_{(min)}$ repetition using the following equation: Percent decline = $[(\text{repetition}_{min} - \text{repetition}_{max})/\text{repetition}_{max}] \times 100$. Furthermore, to provide a more holistic view of MV, PV, MP, and PP during all repetitions within each set the overall maintenance was calculated by the following equation: $\text{Maintenance}_{set} = 100 - [(\text{mean}_{set} - \text{repetition}_{max})/\text{repetition}_{max}] \times 100$. As a result, the variables of MV and PV decline (MVD and PVD, respectively), MP and PP percent decline (MPD and PPD, respectively), MV and PV maintenance (MVM and PVM, respectively), and MP and PP maintenance (MPM and PPM, respectively) were calculated. Finally, the number of repetitions performed during each of the protocols above the 10 and 20% loss thresholds for mean velocity ($MV_{90\%}$ and $MV_{80\%}$), peak velocity ($PV_{90\%}$ and $PV_{80\%}$), mean power ($MP_{90\%}$ and $MP_{80\%}$), and peak power ($PP_{90\%}$ and $PP_{80\%}$) was measured to assess the number of "effective" repetitions being performed.

Statistical Analyses

Means and SDs were calculated for all variables. A two-way 2 × 3 (set structure × load) repeated-measures analysis of variance (ANOVA) was used to compare the mean values of MVD, PVD, MPD, PPD, MVM, PVM, MPM and MPM per protocol.

An individual 2 × 3 (set structure × load) repeated measures ANOVA was computed to compare session RPE scores of each load per protocol. In addition, individual 2 x 3 (set structure x load) repeated measures ANOVA was used to compare the number of repetitions performed within each protocol for $MV_{90\%}$, $MV_{80\%}$, $PV_{90\%}$, $PV_{80\%}$, $MP_{90\%}$, $MP_{80\%}$, $PP_{90\%}$ and $PP_{80\%}$.

When significant main effects or interactions were obtained, a Holm's Sequential Bonferroni follow-up test was performed to control for type I error and assess pairwise comparisons. Hedge's *g* effect sizes with 90% confidence intervals (90%CI) were used to determine practically relevant magnitude of difference, which can be interpreted as: $d < 0.2$ (trivial), $d = 0.2–0.5$ (small), $d = 0.5–0.8$ (moderate), and $d > 0.8$ (large). Hedge's *g* was chosen in preference of Cohen's *d* in order to account for the small sample sizes. To avoid an exasperating number of effect sizes, only moderate and large values were reported and discussed. An a priori level of significance was set at $p < .05$ for all tests. All statistical analyses were performed using SPSS version 23.0 (IBM, Armonk, NY, United States).

Results

When all repetitions during a single protocol were averaged together, there was no significant set structure*load interaction for MVD (p = .270), MVM (p = .182), PVD (p = .180), PVM (p = .161), MPD (p = .258), MPM (p = .226), PPD (p = .544), or PPM (p = .644). However, there were significant main effects of set structure for MVD (p = .018), MVM (p = .006), PVD (p = .009), PVM (p < .001), MPD (p = .012), MPM (p = .004), and PPD (p = .021), but not for PPM (p = .191) (Table 1).

When analysing the total number of repetitions performed above the adopted thresholds (i.e. 10 and 20% loss) during a single protocol that were averaged together, there was a significant set structure*load interaction for $PV_{80\%}$ (p = .029), but not for $MV_{90\%}$ (p = .168), $MV_{80\%}$ (p = .248), $PV_{90\%}$ (Pp = .165), $MP_{90\%}$ (p = 0.117), $MP_{80\%}$ (p = 0.233), $PP_{90\%}$ (p = .741) and $PP_{80\%}$ (p = .904) (Table 2). However, there was a main effect of set structure for $MV_{90\%}$ (p = .018), $MV_{80\%}$ (p = .010), $PV_{90\%}$ (p = .005), $PV_{80\%}$ (p = .004), $MP_{90\%}$ (p = .001), $MP_{80\%}$ (p = .035), but not for $PP_{90\%}$ (p = .741) and $PP_{80\%}$ (p = .355) (Table 2).

When all session RPE scores during a single protocol were averaged together, there was a significant set structure*load interaction (p = .014), as well as main effect of set structure (p < .001) and load (p < .001) (Table 3).

Discussion

This study was designed to investigate the effectiveness of rest redistribution for maintaining velocity and power output during clean pulls at different loading magnitudes with the aim of functioning as a free ad-hoc alternative to VBT. The major findings from the present study were that RR allowed participants to perform more repetitions above 90 and 80% velocity- and power-loss thresholds for all variables, except $PP_{90\%}$ and $PP_{80\%}$, compared to their respective TS protocols. In addition, the shorter, but more frequent inter-set rest periods during RR generally allowed for greater MVM, MPM, PVM and PPM than TS while also resulting in less MVD, MPD, PVD, PPD and RPE, whereby differences were more prominent as the loading magnitude increased. Therefore, when the long inter-set rest periods of TS were redistributed to create shorter, but more frequent sets, velocity and power were better maintained.

To our knowledge, only two other studies have taken a similar approach to assess the ability of RR to maintain velocity and power output above certain thresholds (Tufano et al., 2017b, 2018), but those studies used cluster sets inclusive of extra rest periods, did not have a traditional set protocol, and either analysed the effects of a single load over multiple sets or assessed an undetermined number of repetitions per set. The unique approach of this study allowed to assess the ability of RR to potentially serve as an ad-hoc alternative to different velocity-and power-based thresholds (i.e. 90 and 80% loss) using the same number of repetitions and total rest time, over multiple sets and loading magnitudes. In doing so, our data show that participants were able to perform more repetitions during RR above the 90 and 80% thresholds, even more so at higher intensities (Figures 2 and 3). These findings are somewhat in agreement with a previous study that showed that redistributing total rest to create 36 sets of 1 repetition with 12 s of inter-set rest allowed participants to perform all 36 repetitions of back squat exercise above the 80% velocity-based threshold, but the same did not happen when rest was redistributed to make 9 sets of 4 with 52.5 s of inter-set rest (Tufano et al., 2017b). Although the exercises and loads were different between that study and the present one, it may be possible that rest-redistribution is particularly effective when exaggerating a shorter, but more frequent set concept, yet future studies should be conducted to substantiate such a claim. Additionally, the results of the present study expand on previous findings demonstrating that the differences between RR and TS were more profound when the velocity and power thresholds were stricter (i.e. 90%) and when the external load was greater (i.e. 120% > 100% > 80%).

Table 1

Means and standard deviations and results of analysis of variance between Rest Redistribution sets (RR) and Traditional sets (TS) in MVM, PVM, MPM, PPM, MVD, PVD, MPD and PPD across 80%, 100%, and 120% 1RM.

		RR		TS					
		M	*SD*	*M*	*SD*	*F*	*g*	*LCI*	*UCI*
MVM	80%	92.99	1.82	91.17	5.63	1.66	0.42	-0.18	1.03
	100%	92.58	2.42	91.34	2.14	1.89	0.50†	-0.12	1.09
	120%	92.71	3.24	88.35	4.99	12.86**	1.05††	0.41	1.69
PVM	80%	92.68	2.73	90.84	4.06	3.63	0.52†	-0.09	1.13
	100%	93.58	2.53	91.96	1.88	5.59	0.70†	0.09	1.32
	120%	91.57	2.44	87.79	3.42	17.70**	1.24††	0.58	1.89
MPM	80%	91.66	3.77	89.43	7.16	1.42	0.38	-0.23	0.99
	100%	92.64	3.25	91.13	2.14	2.03	0.53†	-0.08	1.15
	120%	92.56	2.54	87.68	4.78	16.22**	1.24††	0.58	1.90
PPM	80%	87.44	6.13	87.11	6.67	0.01	0.01	-0.63	0.58
	100%	88.03	4.35	86.80	3.64	0.56	0.30	-0.31	0.90
	120%	85.55	4.02	82.79	8.67	1.43	0.40	-0.21	1.00
MVD	80%	16.20	6.47	18.62	9.51	0.66	-0.29	-0.89	0.31
	100%	16.83	7.38	20.27	6.50	1.76	-0.48	-1.09	0.13
	120%	15.86	6.23	24.13	8.75	8.51*	-1.06††	-1.70	-0.42
PVD	80%	14.57	3.69	17.78	7.05	4.10	-0.56†	-0.96	0.25
	100%	15.28	7.42	17.32	2.50	0.85	-0.36	-0.96	0.25
	120%	17.52	3.79	24.44	7.13	9.45*	-1.18††	-1.83	-0.53
MPD	80%	17.91	7.14	20.63	10.53	0.75	-0.29	-0.90	0.31
	100%	17.09	7.50	20.52	6.47	1.64	-0.48	-1.08	0.13
	120%	16.00	6.04	24.80	8.39	10.29*	-1.17††	-1.82	-0.52
PPD	80%	23.32	7.37	24.37	8.89	0.15	-0.13	-0.73	0.48
	100%	23.61	8.33	26.21	5.49	0.76	-0.36	-0.96	0.25
	120%	26.53	5.11	32.25	9.60	5.41*	-0.72†	-1.34	-0.10

Note. MVM – Mean velocity maintenance; PVM – Peak velocity maintenance; MPM – Mean power maintenance; PPM – Peak power maintenance; MVD – Mean velocity decline; PVD – Peak velocity decline; MPD – Mean power decline; PPD – Peak power decline; g – Hedges' g; *LCI* – lower confidence interval; *UCI* – upper confidence interval; **(p < 0.05); ** (p < 0.01); † (g = 0.5-0.79); †† (g > 0.8).*

Table 2

Means and standard deviations and results of analysis of variance between Rest Redistribution sets (RR) and Traditional sets (TS) in $MV_{80\%}$, $MV_{90\%}$, $PV_{80\%}$, $PV_{90\%}$, $MP_{80\%}$, $MP_{90\%}$, $PP_{80\%}$ and $PP_{90\%}$ across 80%, 100%, and 120% 1RM.

		RR		TS					
		M	*SD*	*M*	*SD*	*F*	*g*	*LCI*	*UCI*
$MV_{80\%}$	80%	17.80	0.41	16.67	3.85	1.24	0.40	-0.20	1.01
	100%	17.60	0.63	17.20	1.15	1.75	0.42	-0.19	1.03
	120%	17.60	0.91	15.13	3.38	6.40	0.97†	0.34	1.61
$PV_{80\%}$	80%	17.87	0.52	17.07	2.84	1.76	0.38	-0.22	0.99
	100%	17.8	0.56	17.93	0.26	0.65	-0.30	-0.90	0.31
	120%	17.53	0.83	15.27	3.20	8.92*	0.94††	0.31	1.58
$MP_{80\%}$	80%	17.13	2.56	16.2	4.09	0.52	0.27	-0.34	0.87
	100%	17.53	0.74	17.07	1.22	1.78	0.45	-0.16	1.06
	120%	17.67	0.82	14.93	3.75	6.98	0.98††	0.34	1.62
$PP_{80\%}$	80%	14.93	4.61	14.73	4.35	0.02	0.04	-0.56	0.64
	100%	15.00	3.70	14.40	3.07	0.19	0.17	-0.43	0.77
	120%	13.07	4.52	11.93	4.56	0.68	0.24	-0.36	0.85
$MV_{90\%}$	80%	13.60	2.87	12.67	4.39	0.63	0.24	-0.36	0.85
	100%	13.27	4.37	11.27	2.91	2.31	0.52†	-0.09	1.13
	120%	13.20	3.67	8.93	4.77	7.69*	0.98††	0.34	1.61
$PV_{90\%}$	80%	12.80	4.35	11.67	4.45	0.69	0.25	-0.35	0.85
	100%	14.40	3.85	12.13	2.82	6.03	0.65†	0.04	1.27
	120%	11.87	3.96	7.67	3.33	11.63**	1.12††	0.47	1.76
$MP_{90\%}$	80%	12.47	4.69	10.80	4.78	1.71	0.34	-0.26	0.95
	100%	13.40	4.48	10.87	2.85	3.05	0.66†	0.04	1.27
	120%	13.13	3.80	7.53	4.75	15.62**	1.27††	0.61	1.93
$PP_{90\%}$	80%	7.40	4.55	8.33	5.50	0.34	-0.18	-0.78	0.42
	100%	8.13	4.42	6.47	3.31	1.15	0.41	-0.19	1.02
	120%	5.53	2.90	5.47	2.72	0.01	0.02	-0.58	0.62

*Note. $MV_{80\%}$ – Mean velocity 80% threshold; $PV_{80\%}$ – Peak velocity 80% threshold; $MP_{80\%}$ – Mean power 80% threshold; $PP_{80\%}$ – Peak power 80% threshold; $MV_{90\%}$ – Mean velocity 90% threshold; $PV_{90\%}$ – Peak velocity 90% threshold; $MP_{90\%}$ – Mean power 90% threshold; $PP_{90\%}$ – Peak power 90% threshold; g – Hedges' g; LCI – lower confidence interval; UCI – upper confidence interval; *($p < 0.05$); ** ($p < 0.01$); † ($g = 0.5$-0.79); †† ($g > 0.8$).*

Table 3

Means and standard deviations, and results of analysis of variance between Rest Redistribution sets (RR) and Traditional sets (TS) in session RPE scores across 80%, 100%, and 120% 1RM.

	RR		TS					
	M	*SD*	*M*	*SD*	*F*	*g*	*LCI*	*UCI*
80%	2.63	0.90	3.37	0.74	9.88**	-0.87††	-1.50	-0.24
100%	3.80	1.00	5.37	1.22	21.54**	-1.37††	-2.04	-0.70
120%	5.97	1.33	7.77	1.15	65.42**	-1.41††	-2.08	-0.74

Note. g – Hedges' g; *LCI* – lower confidence interval; *UCI* – upper confidence interval; **(p < 0.05); ** (p < 0.01); † (g = 0.5-0.79); †† (g > 0.8).*

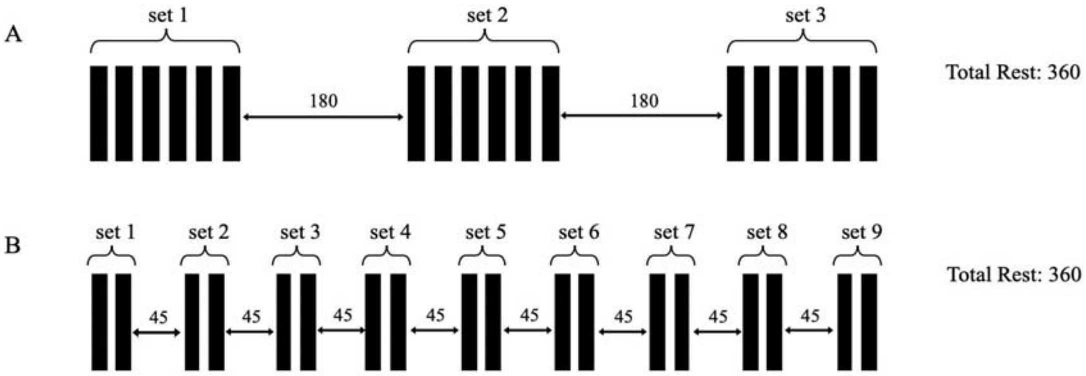

Figure 1

Set structure protocols. Traditional sets, 3 sets of 6 with 180 seconds of inter-set rest (panel A). Rest redistribution sets, 9 sets of 2 with 45 seconds of inter-set rest (panel B).

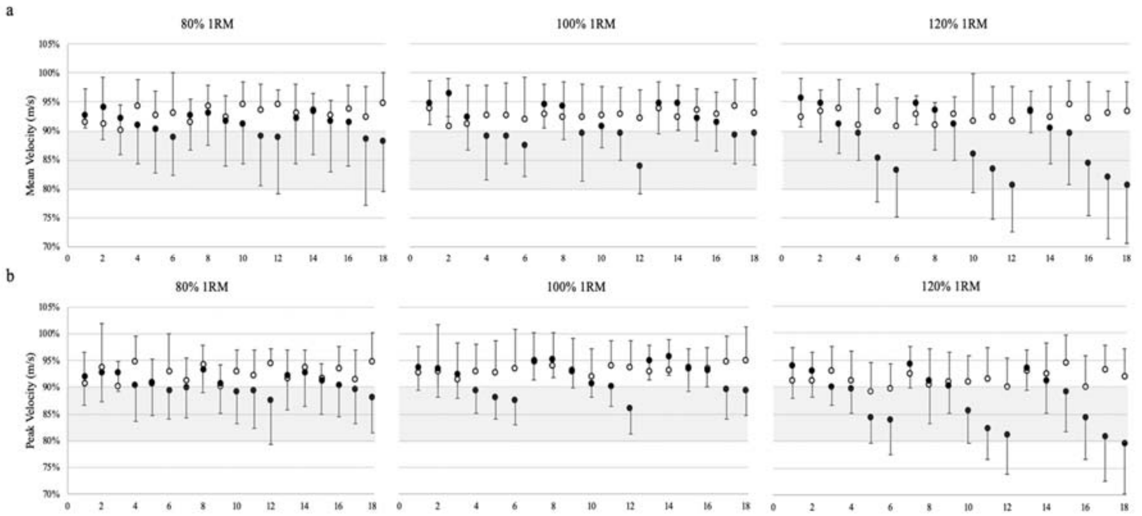

Figure 2

Means and standard deviations of repetitions performed during rest redistribution sets (RR) at 80%, 100% and 120% intensity (open circles), and traditional sets (TS) at 80%, 100% and 120% intensity (closed circles) across 18 repetitions for: mean velocity output (panel A) and peak velocity output (panel B). The shaded area represents the range between 90 and 80% thresholds.

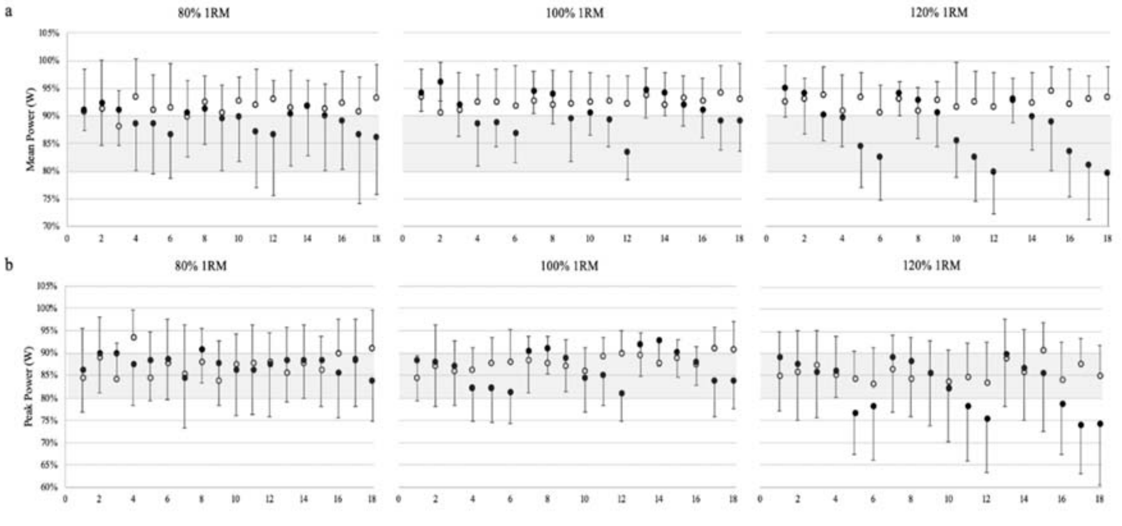

Figure 3

Means and standard deviations of repetitions performed during rest redistribution sets (RR) at 80%, 100% and 120% intensity (open circles), and traditional sets (TS) at 80%, 100% and 120% intensity (closed circles) across 18 repetitions for: mean power output (panel A) and peak power output (panel B). The shaded area represents the range between 90 and 80% thresholds.

On a methodological note, when describing how fatiguing certain RT set structures can be, many researchers use the decline of velocity or power to substantiate their claims. These decline variables are often calculated as the absolute or percentage difference between the first and the final repetition (Tufano et al., 2016). In this manner, decrements in movement velocity and power have been shown to range between 20 and 37% during traditional sets, depending on the exercise and the number of repetitions being performed (Gorostiaga et al., 2012, 2014; Hardee et al., 2012b; Oliver et al., 2016; Tufano et al., 2016). However, using only decline calculations that include solely two repetitions, the remaining repetitions between the first repetition and the last are not accounted for, thus possibly resulting in misleading conclusions about how fatiguing an exercise session is. In that regard, it may be more appropriate to use maintenance calculations whereby all repetitions are expressed relative to the best repetition, and then the average decline of all repetitions is taken into consideration. For example, one study reported a decline in velocity and power of 23% during high volume back squats, but when all repetitions were taken into account (i.e. maintenance was calculated), the authors reported a maintenance of 92%, resulting in an average decline of only 8% (Tufano et al., 2016). Similar findings have been observed in the present study where TS resulted in an MVD and PVD of between 14 and 17% each depending on the intensity, but MVM and MPM were between 92 and 88% each. These differences, especially in decline variables, between the findings could likely be explained by the different exercise and multiple loading magnitudes being used in the present study. Given the large discrepancy between decline and maintenance variables, one should address both, as they may each tell a different story.

On a practical note, the general practice of VBT, the calculation of decline variables, and the calculation of maintenance variables generally assume that that the best repetitions occur at the beginning of a set or a training session. However, this might not always be the case, as can be seen in the present study (Figures 2 and 3). Although we did not analyse the differences between when participants performed their fastest or most powerful repetition, it generally occurred between the first and third repetitions while some of them had their fifth repetition as their best. This means that although the force-velocity relationship is linear, the repetition-velocity relationship might not always be linear in practice. Therefore, coaches who use VBT should be aware of this, since participants of the present study were trained lifters and rarely had their best repetition as their first. Considering these points, we would like to highlight the importance of not basing fatigue on the first repetition of a training set, but actually identifying the best and the worst repetition, using those and all of the other repetitions within a training session to provide a more holistic objective view on velocity and power output.

Lastly, considering the fact that RR allowed for a better maintenance and lower decline of movement velocity and power output than TS, it was expected that the RPE scores would be lower during RR. As the loading magnitude increased, the present study showed a linear increase of the difference in RPE scores between RR and TS (Table 1). Since the RPE has been shown to simultaneously increase as movement velocity decreases when lifting the same load with maximal intent (Hardee et al., 2012a; Mayo et al., 2014), the results of the present study further highlight the relationship between velocity loss during RT and the degree of fatigue. This is not the first study that showed lower perceptual responses while implementing more frequent rest periods as opposed to TS during RT. For example, in one study (Hardee et al., 2012a), participants performed three traditional sets of six power cleans using 80% RM with 3 min of inter set rest resulting in RPE scores of 6, 7.5 and 9 after each set. However, RPE scores decreased to 4, 5 and 6 when more frequent rest periods (i.e. after every repetition) were adopted (Hardee et al., 2012a). In the current study, RPE scores progressively increased from T80 (3.37 ± 0.74), T100 (5.37 ± 1.22) to TS120 (7.77± 1.15), and were also decreased when more frequent rest periods were allowed (RR80 (2.63 ± 0.9), RR100 (3.80 ± 1.0) and RR120 (5.97 ± 1.33)). In both studies, the RPE served as an accurate measure of perceived exertion, evidenced by progressive decrements in movement velocity and power as the number of sets or loading magnitude increased. Since the RPE reflected changes in movement velocity and power output, it has been proven again to be a valid tool to determine a degree of fatigue, which is quick and easy to use.

Finally, based on the findings of the present study, the RR protocols seem to allow for a better overall maintenance of velocity than TS at all loads, especially at heavier loads while also ensuring lower perceptual responses of participants. Additionally, although the average number of repetitions performed within the 10 and 20% velocity loss thresholds were greater during RR, individual differences were not compared in this study, and it is possible that certain athletes may fatigue more than others. Nevertheless, this is the first study to show the potential of RR protocols to serve as an ad-hoc alternative to common VBT thresholds. Future research should seek to determine whether different set and repetition schemes, during different exercises and using multiple loading magnitudes, could be associated with different velocity- and/or power-based thresholds in order to provide practitioners, who may not use VBT devices, with benefits of VBT in a more practical way.

The present study shows the ability of RR to maintain movement velocity and power output to a greater extent when compared to TS while performing clean pulls at different loads, especially at higher loads (100 and 120% 1RM). However, RR might not be that beneficial when the protocol is not extremely fatiguing (i.e. 80% 1RM). Furthermore, coaches should be aware that although the force-velocity relationship is linear, the repetition-velocity relationship might not always be in practice. Therefore, caution should be taken while using VBT percentage-based thresholds and other variables which assume the linearity of the repetition-velocity relationship (i.e. 1st repetition is always the best). Lastly, strength and conditioning professionals who wish to implement VBT principles during training, but who do not wish to purchase or use VBT equipment, can likely encourage similar training stimuli by redistributing traditional long inter-set rest periods to create shorter, but more frequent sets.

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