

# ANALYSIS OF TRAINING LOAD AND PERFORMANCE IN DESIGNING SMART BODYWEIGHT POWER TRAINING: EFFECTS OF SET STRUCTURE IN VERTICAL JUMPING SESSIONS

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## Abstract:

The purpose of this study was to investigate the role of set structures in designing bodyweight power training (BWPT). Specifically, we compared the effects of the cluster set structure undulating variant (CSS<sub>UV</sub>) and the traditional set structure (TSS) on training load and performance during vertical jumping sessions. Sixteen active males participated in this study. We designed four training sessions that consisted of 144 countermovement jumps distributed into 12 sets, where the number of repetitions varied for the CSS<sub>UV</sub> sessions, whereas for TSS sessions the number of repetitions was fixed. In addition, both of the applied set structures included sessions with short (60 seconds) and long rest periods (120 seconds), while training volume was separately analysed for the first six sets (small volume) and the last six sets (large volume). External load, internal load, and performance variables were calculated. The results suggest that CSS<sub>UV</sub> allows superior utilization of applied external load, reduction of internal load and overall higher performances that are maintained during entire training session compared to TSS ( $p < .05$ ). The present study provides important findings about advantages of CSS<sub>UV</sub> over TSS in terms of external load, internal load, and performances during vertical jumping sessions, and therefore, it might be more suitable approach to designing BWPT.

**Key words:** set configuration, cluster set structure, traditional set structure, training volume, rest duration

## Introduction

Set structure has been considered as an important factor in programming training for development and maintaining muscle power in athletes (Haff, et al., 2008; Suchomel, Nimphius, Bellon, & Stone, 2018). Currently, two approaches to designing a set structure in power training are proposed (Haff, et al., 2008; Tufano, Brown, & Haff, 2017): *traditional* and *cluster*. The *traditional set structure* (TSS) is conducted in a continuous manner with fixed number of repetitions and fixed rest periods between the sets (i.e., inter-set rest), whilst the *cluster set structure* (CSS) implies the possibility of manipulation with the number of repetitions both within and between the sets as well as the introduction of additional rest periods within the sets (i.e., intra-set and inter-repetition rest; Haff,

et al., 2008; McGuigan, 2017; Tufano, et al., 2017). However, TSS is more popular and widely used in power training practice, whereas CSS is unjustifiably neglected (Suchomel, et al., 2018), despite numerous confirmations of its valuable advantages that have been summarized and well discussed in a couple of review articles (Haff, et al., 2008; Tufano, et al., 2017). These CSS benefits over TSS entail the possibility to apply larger volume (Arazi, Bagheri, & Kashkuli, 2013), maintain higher intensity (Haff, et al., 2003; Hansen, et al., 2011a; Moreno, Brown, Coburn, & Judelson, 2014), reduce both the objective and subjective athlete's response to effort (Girman, Jones, Matthews, & Wood, 2014; Hardee, et al., 2012a), preserve quality of technique (Hardee, et al., 2013), and maintain level of performance within the entire training session (Hardee, et al., 2012a; Moreno, et al., 2014) as well as achieve more

prominent chronic effects in terms of long-term adaptation to the applied power training (Asadi & Ramírez-Campillo, 2016; Hansen, et al., 2011b).

Regarding the above-mentioned benefits, it is worth mentioning that current classification implies several types and variants of CSS. Namely, Tufano et al. (2017) recognized four main types of CSS: *basic cluster*, *rest-redistribution*, *equal work-to-rest ratio* and *rest-pause method*; while the other notable authority suggested three basic variants (Mcguigan, 2017): *standard*, *ascending* and *undulating*. The last variant of the listed CSSs—the *undulating variant* (CSS<sub>UV</sub>) implying increasing and decreasing external load intensity (i.e., % of 1 repetition maximum) between and within the sets (Haff, et al., 2003), could be of particular importance in the practice of *bodyweight power training* (BWPT), because it provides various possibilities for designing the appropriate set structure. Although the CSS<sub>UV</sub> has been standardly used in resistant training aiming at muscle power development, a different approach needs to be applied when designing BWPT. Namely, external load in terms of training intensity is non-existent and manipulation with training volume within and between sets (i.e., increasing and decreasing the number of repetitions) could be a usable solution. Previous findings proved effectiveness of CSS<sub>UV</sub> within sessions of resistance training aimed to improving maximal power (Haff, et al., 2003), yet there was no such study that explored its potential applicability in any form of BWPT.

To address the above-reviewed potentially important but unresolved issues, we designed an experiment with the main purpose to investigate the effect of different set structures on BWPT. Specifically, we compared the effects of CSS<sub>UV</sub> and TSS on training load and performance during vertical jumping sessions. Within the experimental sessions, *countermovement jumps* (CMJ) were used as one of the most commonly used tests and exercises in BWPT as well as a widely represented task in various sports disciplines. Along with the main independent variable (i.e., set structure), the effects of rest period duration and training volume were explored as additional independent variables that could provide more comprehensive findings. We hypothesized that the applied CSS<sub>UV</sub> would provide a higher external load (i.e., quantity and quality of work done), lower internal load (i.e., objective and subjective indicators of effort) along with a better maintenance of performance levels (i.e., slower declining) compared to TSS. We expected that the obtained experimental data could significantly contribute to the understanding of CSS<sub>UV</sub> potential benefits for designing vertical jumping sessions, which is of utmost importance for smart program-

ming of power training. Therefore, we expected not only to reveal some fundamental principles of set structure application, but also to provide potentially valuable practical information regarding the CSS<sub>UV</sub> implementation in standard BWPT.

## Materials and methods

### Participants

Sixteen male students of the Faculty of Sport and Physical Education participated in this study. Characteristics of the participants were the following: age  $24.25 \pm 3.97$  years; body height  $1.84 \pm 0.06$  m; body mass  $82.54 \pm 6.51$  kg; and body mass index  $24.43 \pm 1.73$  kg/m<sup>2</sup>. The participants did not report any medical problem or recent injuries that could have compromise their performance. Prior to the experiment, all participants received a complete explanation regarding the purpose and procedures of the study as well as possible risks. They were also required to sign an informed consent document. The study was approved by the Institutional Review Board.

### Experimental design

This study, of a within-subject design, explored the effects of different set structures, rest period duration and training volume in vertical jumping sessions on the external load, internal load and performances. The participants attended one familiarization session followed by four randomized experimental sessions with at least five-day breaks between them. Each of the experimental sessions consisted of 144 CMJs distributed into 12 sets. However, depending on the applied set structure, the number of jumps was different among the sets. Specifically, during the CSS<sub>UV</sub> sessions, the number of jumps varied from 6 to 18 per set and from 1 to 9 per subset, whilst the TSS sessions' number of jumps was fixed on 12 per set (for details see Figure 1). Also, we explored the effects of *short-rest* and *long-rest* duration among the sets (i.e., 60 and 120 seconds in total, respectively), while the distribution of rest periods was dissimilar within and between the sets depending on the applied set structure. Specifically, the CSS<sub>UV</sub> *short-rest* session consisted of two intra-set rest periods of 15 seconds and one inter-set rest of 30 seconds (i.e., 60 seconds of rest in total), and the *long-rest* session included two intra-set rest periods of 30 seconds and one inter-set rest of 60 seconds (i.e., 120 seconds of rest in total), while the TSS *short-rest* session included one inter-set rest of 60 seconds, and the *long-rest* session consisted of one inter-set rest of 120 seconds. Details of the designed and applied four vertical jumping training sessions are presented in Table 1.

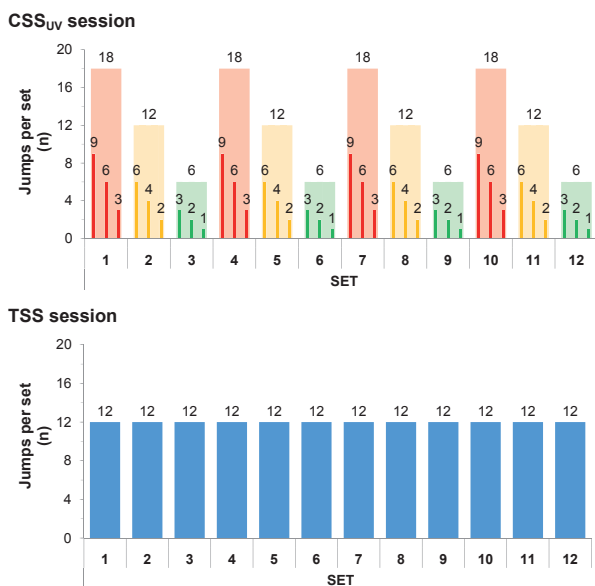


Figure 1. Graphic display of the distribution of the number of vertical jumps per set for the cluster set structure undulating variant ( $CSS_{UV}$ ) and traditional set structure (TSS).

## Procedure

The experiment was conducted in the spring between 9 a.m. and 14 p.m. in the laboratory facility that was maintained at the air temperature between 18 and 22 °C. The familiarization session was designed to collect standard anthropometric measures and to inform the participants about the procedures (i.e., type of exercise, monitoring tools, and specific instructions). Anthropometric measures were taken by the same experimenter according to the standard procedures recommended by the International Society for the Advancement of Kinanthropometry (Norton, et al., 2000). Body height and body mass were measured to the nearest 0.5 cm and 0.1 kg, respectively. Thereafter, body mass index (BMI) was also calculated. In the present study CMJs with the hands on the hips were applied and they were repeated according to the corresponding set structure and rest period duration. The participants were asked to refrain from strenuous activity for five days before and after each experimental session.

Prior to each experimental session, heart rate monitor equipment had been placed on the participants (watch on the left hand and belt on the chest) and then 15-minute warm-up followed (i.e., 5-minute bicycle-ergometer riding, 5-minute dynamic stretching, and 5-minute individual preparation). Thereafter, the measurement of maximal jumping performances was performed as a base to evaluate performances during the sessions.

After this procedure, the main part of the experimental session started and the participants performed CMJs with the inter-repetition rest of approximately one second. Immediately after the set had been completed, the specific feedback from

Table 1. The design of training sessions with short rest and long rest variation for two different set structures: the cluster set structure undulating variant ( $CSS_{UV}$ ) and traditional set structure (TSS)

Design variable	$CSS_{UV}$		TSS	
	Short rest	Long rest	Short rest	Long rest
1 <sup>st</sup> intra-set rest period (s)	15	30	/	/
2 <sup>nd</sup> intra-set rest period (s)	15	30	/	/
Inter-set rest period (s)	30	60	60	120
Total set rest (s)	60	120	60	120
Total session rest (s)	720	1440	720	1440
Total number of sets (n)	12	12	12	12
Total number of jumps (n)	144	144	144	144

the participants was required. Namely, the specific data related to internal responses to exertion were collected within the 5-second period from the start and before the end of each between-set rest period (for details, see further text).

## Data collection and analysis

**Equipment and instruments.** The kinetic and kinematic data were collected via two force plates (dimensions 0.4 x 0.6 m, INC., Newton MA, USA) on which participants performed CMJs following the guidelines provided by Vanrenterghem, De Clercq, and Van Cleven (2001). Signals were collected with ground reaction forces frequency at 1 kHz. Raw data were processed using LabVIEW custom designed program for this experiment (LabVIEW version 18.0, National Instruments Corporation, Austin, TX, USA), by which corresponding kinetic and kinematic variables were calculated. The feedback from the participants was collected via Borg CR-10 scale (Robertson, et al., 2003) and perceived recovery scale (Machado, et al., 2018), while heart rate data were acquired using Sunnto M5 (Sunnto, Finland).

**External load.** We assessed external load during concentric jump phases and calculated *total work* ( $A_{tot}$ ) as a measure of external load quantity (i.e., training volume) and *maximal power* ( $P_{max}$ ) as a measure of external load quality (i.e., training intensity). Specifically,  $A_{tot}$  was calculated as mean power multiplied by time, while instantaneous  $P_{max}$  was calculated by multiplying the vertical ground reaction force with the velocity of the centre of mass (Blazevich, 2017).

**Internal load.** At the beginning of each inter-set rest period, participants' corresponding internal responses to exertion and recovery were collected. Specifically, we used Borg CR-10 scale for collecting subjective assessments such as rating of perceived exertion for legs ( $RPE_{legs}$ ) and rating of perceived exertion for breath ( $RPE_{breath}$ ), while the heart rate (HR) was employed as an objective measure of

internal load. Also, at the end of each between-set rest periods rating of perceived recovery (RPR) was collected via perceived recovery scale as a subjective assessment of recovery for the next set of jumps.

**Performances.** The measurement of maximal jumping height ( $JH_{max}$ ) was conducted via 15 repetitions of CMJs with approximately 10-15-second pauses between consecutive jumps. The command was always to jump as high as possible when performing CMJs. In line with the previous studies performed according to a similar procedure (Pereira, et al., 2011) and participants' reports, fatigue was never an issue. The average value of the highest five CMJs was a measure of performance and it was measured for each experimental session separately. This measure was the baseline data (i.e., criterion) to calculate the decline or preservation of performance, further expressed as a percentage of maximal jumping height ( $\%JH_{max}$ ) for every performed jump within each of the experimental sessions. To test the potential effects of unwanted variability, we explored inter-session reliability (for details, see section Statistical analysis).

The obtained data of external load, internal load and performance were analysed for the first six sets (i.e., *small volume*; from the 1st to the 72nd jump) and last six sets (i.e., *large volume*; from the 73rd to the 144th jump) separately for each participant and experimental session. All data were averaged for both data sets, except for  $A_{tot}$  where we calculated the sum. Note that beside the main independent variables (i.e., *set structure* and *rest period duration*), this approach to data analysis enabled us to explore the effects of *training volume* as an additional independent variable.

## Statistical analysis

Descriptive statistics were calculated for all experimental data as mean and standard deviation (SD). Normality of the distribution for all data sets was confirmed by Shapiro-Wilks test ( $p > .05$ ).

Regarding the reliability evaluation of  $JH_{max}$  among four experimental sessions, the intraclass correlation coefficient (ICC, model 3,1) was used to determine inter-session between-participants reliability (Weir, 2005), whereas the coefficient of variation (CV) was calculated as an indicator of within-participant variation (Hopkins, 2015). Ninety-five percent confidence intervals (95% CI) were determined for ICC and CV. Based on previously published reliability studies on jumping tasks and to maximize the potential usefulness of the measurement, the following criteria were used to determine acceptable ( $ICC \geq 0.80$ ,  $CV \leq 10\%$ ) and high ( $ICC \geq 0.90$ ,  $CV \leq 5\%$ ) reliability (García-Ramos, et al., 2020; James, et al., 2017; Lindberg, et al., 2021). In addition, a one-way repeated measures analysis of variance (ANOVA) was used to detect possible systematic bias in terms of fatigue

or learning effects (Thomas, Nelson, & Silverman, 2010).

A repeated measures three-way ANOVA was used to establish effects of the applied independent variables (i.e., *set structure*:  $CSS_{UV}$  vs. TSS; *rest period duration*: short rest vs. long rest; and *training volume*: small vs. large) on the dependent variables (*external load*:  $A_{tot}$ ,  $P_{max}$ ; *internal load*:  $RPE_{legs}$ ,  $RPE_{breath}$ , HR, and RPR; and *performance*:  $\%JH_{max}$ ). A Greenhouse-Geisser adjustment was made to the degrees of freedom in case of sphericity violation. The follow-up ANOVAs statistical analyses were conducted according to procedures explained in detail (Howell & Lacroix, 2012). When the interactions or main effects were revealed, the Bonferroni *post-hoc* test with adjustment was applied (Vincent & Weir, 2012).

According to Cohen (2013), the magnitude of difference was tested by means of effect size (ES), where the difference was considered either very small (0.01), small (0.2), moderate (0.5), large (0.8), very large (1.2) or huge (larger than 2.0) for the *post-hoc* test (Sawilowsky, 2009), whereas the eta squared ( $\eta^2$ ) was calculated for the ANOVAs with the following classification for magnitude effects (Field, 2013): no effect ( $\eta^2 < 0.04$ ), minimum effect ( $0.04 < \eta^2 < 0.25$ ), moderate effect ( $0.25 < \eta^2 < 0.64$ ) and strong effect ( $\eta^2 > 0.64$ ). A significant level of  $p < .05$  was used for all comparisons. All statistical procedures were done by SPSS version 20.0 (SPSS Inc., Chicago, IL, USA) and Microsoft Office Excel 2016 (Microsoft Corporation, Redmond, WA, USA).

## Results

### Reliability of maximal jumping performance

Descriptive and reliability data of baseline performance (i.e.,  $JH_{max}$ ) across all four experimental sessions are presented in Table 2. Overall, the obtained results suggested exceptional inter-session reliability of  $JH_{max}$  data. Specifically, the between-participants reliability assessed through the four experimental sessions was excellent ( $ICC > 0.9$ ), while the within-participant variability was low ( $CV < 5\%$ ). In addition, the results of one-way repeated measures ANOVA revealed no significant differences among the experimental sessions ( $p > .05$ ).

### External load

**Total work.** The obtained results for  $A_{tot}$  are displayed in Figure 2a. Repeated-measures three-way ANOVA revealed no significance either for three-way or two-way interactions. Additionally, the main factors analysis showed that neither *set structure*, *rest period duration* or *training volume* reached the significance level ( $p > .05$ ).

Table 2. Descriptive and reliability data of maximum jumping performances as a baseline measure across all four experimental sessions

Variable	CSS <sub>UV</sub>				TSS			
	Short rest		Long rest		Short rest		Long rest	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
JH <sub>max</sub> (m)	0.366	0.048	0.367	0.054	0.368	0.053	0.365	0.048
ICC (95% CI)	0.986 (0.970-0.995)							
CV (95% CI)	3.4% (2.8-4.3%)							
p-value	0.973							

Note. JH<sub>max</sub> – maximal jumping height; ICC – intraclass correlation coefficient; 95% CI – ninety-five percent confidence intervals; CV – coefficient of variation.

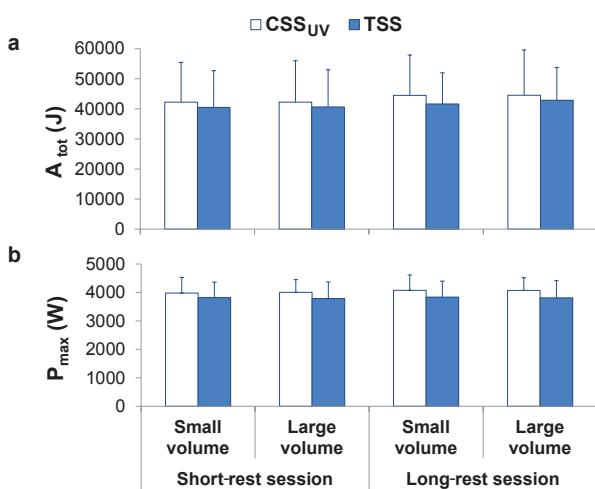


Figure 2. Graphic display of means and standard deviations of external load variables for the cluster set structure undulating variant (CSS<sub>UV</sub>) and traditional set structure (TSS), rest period duration (short and long) and training volume (small and large): a) total work ( $A_{tot}$ ) – as a quantitative measure of load expressed in joule (J), and b) maximal power ( $P_{max}$ ) – as a qualitative measure of load expressed in watts (W).

**Maximal power.** Descriptive data of  $P_{max}$  are presented in Figure 2b. The obtained results confirmed that only *set structure* × *training volume* interaction reached significance with a moderate effect size magnitude ( $p = .009$ ,  $\eta^2 = 0.379$ ). Further, *post-hoc* tests showed advantage of CSS<sub>UV</sub> relative to TSS sessions for both the small volume ( $p = .000$ ;  $ES = 1.23$ ) and large volume ( $p = .000$ ;  $ES = 1.28$ ). However, within TSS sessions, values of  $P_{max}$  for small volume were significantly higher compared to large volume ( $p = .009$ ;  $ES = 0.74$ ), while within CSS<sub>UV</sub> sessions, significance was not reached between the applied levels of training volume ( $p = .341$ ).

## Internal load

**Rating of perceived exertion for legs.** The obtained results for  $RPE_{legs}$  are displayed in Figure 3a. Repeated-measures three-way ANOVA revealed that only the *set structure* × *training volume* interaction was significant with a strong effect size magnitude ( $p = .000$ ,  $\eta^2 = 0.710$ ). *Post-hoc* tests showed

significantly lower  $RPE_{legs}$  values of the CSS<sub>UV</sub> relative to TSS sessions within both the *small volume* ( $p = .010$ ;  $ES = 0.64$ ) and *large volume* ( $p = .000$ ;  $ES = 1.47$ ). Similarly, *small volume* provided significantly lower  $RPE_{legs}$  values compared to *large volume* for both the CSS<sub>UV</sub> ( $p = .000$ ;  $ES = 1.54$ ) and TSS sessions ( $p = .000$ ;  $ES = 2.90$ ).

**Rating of perceived exertion for breath.** Descriptive data of  $RPE_{breath}$  are presented in Figure 3b. As in the previous case, only the *set structure* × *training volume* two-way interaction reached significance, but with a moderate magnitude effect ( $p = .000$ ,  $\eta^2 = 0.628$ ). *Post-hoc* tests showed significantly lower  $RPE_{breath}$  values in favour of CSS<sub>UV</sub> relative to TSS in *small volume* ( $p = .004$ ;  $ES = 0.86$ ) and *large volume* ( $p = .000$ ;  $ES = 1.40$ ). Similarly, *small volume* provided significantly lower values of  $RPE_{breath}$  compared to *large volume* for both the CSS<sub>UV</sub> ( $p = .000$ ;  $ES = 1.65$ ) and TSS sessions ( $p = .000$ ;  $ES = 2.97$ ).

**Rating of perceived recovery.** The obtained results for RPR are displayed in Figure 3c. Repeated-measures three-way ANOVA again confirmed that only the *set structure* × *training volume* interaction showed significance with moderate effects ( $p = .003$ ;  $\eta^2 = 0.446$ ). Additionally, *post-hoc* analysis revealed that values observed in CSS<sub>UV</sub> were higher than in TSS for both the *small* and *large volume* ( $p = .002$ ,  $ES = 0.94$  and  $p = .001$ ,  $ES = 1.02$ ; respectively). Similarly, RPR values were higher for *small* than *large volume*, both in TSS and CSS<sub>UV</sub> sessions ( $p = .000$ ,  $ES = 0.97$  and  $p = .000$ ,  $ES = 2.44$ , respectively).

**Heart rate.** Descriptive data of HR are presented in Figure 3d. In this case, only the *set structure* × *rest period duration* interaction reached significance with moderate effects ( $p = .009$ ,  $\eta^2 = 0.376$ ). Specifically, within CSS<sub>UV</sub> and TSS sessions, there were significantly higher values of HR for *short rest* than *long rest* sessions ( $p = .000$ ,  $ES = 2.23$  and  $p = .000$ ,  $ES = 1.14$ , respectively). Finally, comparisons of *short rest* and *long rest* demonstrated significantly lower values of HR in CSS<sub>UV</sub> than in TSS sessions ( $p = .000$ ,  $ES = 1.43$  and  $p = .000$ ,  $ES = 2.35$ , respectively).

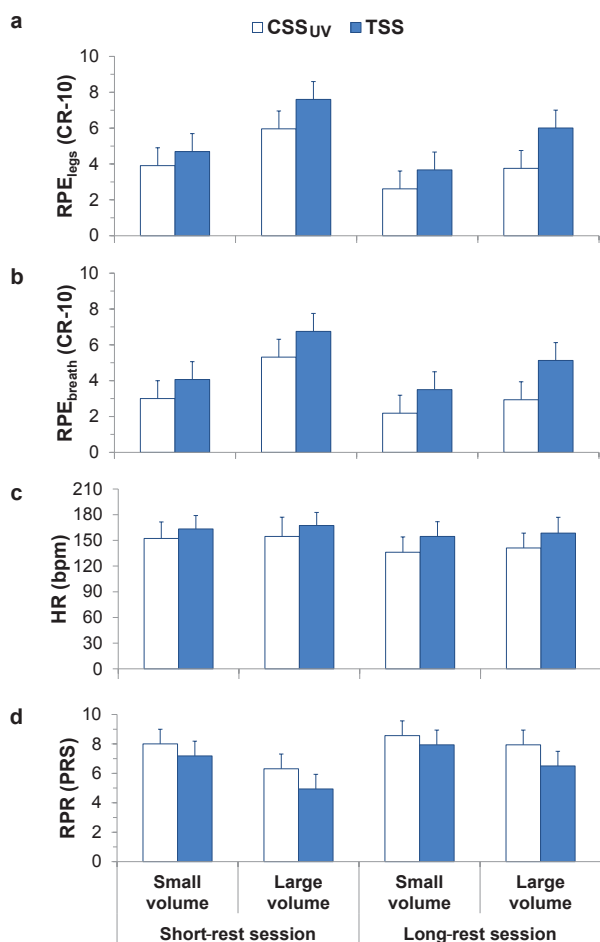


Figure 3. Graphic display of means and standard deviations of internal load variables for the cluster set structure undulating variant (CSS<sub>UV</sub>) and traditional set structure (TSS), rest period duration (short and long) and training volume (small and large): a) rating of perceived exertion for legs (RPE<sub>legs</sub>) – expressed on a category ratio 10-point scale (CR-10), b) rating of perceived exertion for breath (RPE<sub>breath</sub>) – expressed in values from CR-10, c) rating of perceived recovery (RPR) – expressed in values from the perceived recovery scale (PRS), and d) heart rate (HR) – expressed in beats per minute (bpm).

## Performance

*Percentage of maximal jumping height.* Regarding the jumping performance measure of preservation, corresponding results of %JH<sub>max</sub> are displayed in Figure 4. Repeated-measures three-way ANOVA revealed that two-way interactions existed. Firstly, the *set structure* × *training volume* interaction revealed significant and moderate effects ( $p = .037$ ;  $\eta^2 = 0.258$ ). In addition, *post-hoc* test unveiled significantly higher values of %JH<sub>max</sub> for CSS<sub>UV</sub> compared to TSS sessions for both the *small* and *large volume* ( $p = .000$ ,  $ES = 1.30$  and  $p = .000$ ,  $ES = 1.27$ ; respectively). However, significance effect of *training volume* was not detected ( $p = .078$ ) in CSS<sub>UV</sub> sessions, while in TSS sessions %JH<sub>max</sub> values were significantly higher for *small* than for *large volume* ( $p = .002$ ,  $ES = 0.87$ ). Secondly, the *set structure* × *rest period duration* interaction also reached significance with a moderate effect ( $p =$

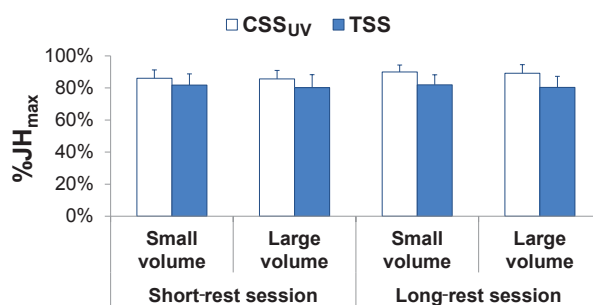


Figure 4. Graphic display of means and standard deviations of the maintenance of maximal jumping height (JH<sub>max</sub>) – expressed in percentage (%) as performance variable for the cluster set structure undulating variant (CSS<sub>UV</sub>) and traditional set structure (TSS) during various rest period durations (short and long) and training volumes (small and large).

$.028$ ;  $\eta^2 = 0.284$ ). Further, *post-hoc* tests showed that considerably higher values of %JH<sub>max</sub> were achieved within CSS<sub>UV</sub> compared to TSS for both the *short rest* and *long rest* sessions ( $p = .000$  and  $p = .006$ , respectively), with large effects ( $ES = 0.80$  and  $1.47$ , respectively). Finally, *post-hoc* test revealed that for *rest period duration* a significant and large effect was detected in favour of *long-rest* sessions with respect to CSS<sub>UV</sub> ( $p = .001$ ;  $ES = 0.98$ ), while it did not make significant impact on %JH<sub>max</sub> values in TSS ( $p = .911$ ).

## Discussion and conclusions

The present study was designed to evaluate and compare the effects of CSS<sub>UV</sub> and TSS on training load and performances during vertical jumping sessions and therefore, we tested one main hypothesis. Specifically, we assumed that CSS<sub>UV</sub> would provide a higher external load, lower internal load along with better preservation of performances compared to TSS. Consistently with our hypothesis, the obtained results mostly confirmed expected benefits of CSS<sub>UV</sub> over TSS, although there were some minor similarities among them. Note that the reliability data for the baseline performance variable (i.e., JH<sub>max</sub>) met the criteria for high inter-session reliability ( $ICC \geq 0.90$ ,  $CV \leq 5\%$ ) and were consistent with findings from previous reliability studies of vertical jumping performance (Cronin, Hing, & McNair, 2004; García-Ramos, et al., 2020; Gathercole, et al., 2015; Hopkins, Schabort, & Hawley, 2001). In the following text, we will focus on the comprehensive interpretation of the main findings for external load, internal load, and performance.

Regarding external load, the present findings suggest that CSS<sub>UV</sub> poses valuable advantages over TSS. Although the differences for quantity measure of external load were not found (i.e.,  $A_{tot}$  values were similar), CSS<sub>UV</sub> allowed overall higher quality of external load during the entire session compared

to TSS (i.e.,  $P_{\max}$  was clearly higher). In addition,  $CSS_{UV}$  provided conditions for maintenance of similar level of  $P_{\max}$  during the entire session, while in TSS sessions performance decreased when training volume increased. These findings of  $P_{\max}$  preservation are similar to those in studies where *rest-redistribution* type of CSS in standard variant (i.e., with the fixed number of repetitions between sets) were applied over TSS during body-weight vertical jump sessions (Moreno, et al., 2014). Previous studies have reported  $P_{\max}$  values for resistance power training using various types of CSS, such as the *basic cluster* (Hardee, et al., 2012a; Hardee, et al., 2012b) and the *equal rest-to-work ratio* method, which belongs to standard variant (Hansen, et al., 2011a). However, to our knowledge, no studies have reported  $A_{\text{tot}}$  values for any type of power training. Note that the mentioned studies demonstrated superiority of the CSS types over TSS when considering variable  $P_{\max}$ . Also, the influence of different types of CSS on external load variables and their comparisons with TSS have been examined in hypertrophy training applying standard variants of CSS types: *basic cluster* (Moir, Graham, Davis, Guers, & Witmer, 2013; Tufano, et al., 2016), *equal work-to-rest ratio* (Iglesias-Soler, et al., 2016), and *rest-redistribution* (Oliver, et al., 2013, 2015, 2016). Like in previous cases, the mentioned studies confirmed that CSS allowed higher power output (i.e.,  $P_{\max}$ ), while there were no differences in total mechanical work (i.e.,  $A_{\text{tot}}$ ), which is in line with the present data. Therefore, it is important to emphasize that in comparison to TSS,  $CSS_{UV}$  allows higher quality of applied external load evenly distributed within vertical jumps training sessions.

From the perspective of internal load measures, the obtained results have also revealed that  $CSS_{UV}$  provides certain benefits comparing to TSS. In that regard, the fact that participants reported a lower rate of perceived effort (i.e., smaller values of  $RPE_{\text{legs}}$  and  $RPE_{\text{breath}}$ ) for  $CSS_{UV}$  sessions and faster recovery during the sessions (i.e., higher values of RPR) could be of particular importance. It is important to note that these findings were emphasized in relation to the training volume applied. Although *post-hoc* analyses revealed that *set structure*  $\times$  *training volume* interactions were simple (i.e., with similar trends of data), the subsequent effect size analyses disclosed additional benefits in favour of  $CSS_{UV}$ . Specifically, dissimilar magnitudes of differences were observed for all the three variables within both the small and large training volume, with the exception of RPR for the large volume (for details, see the Results section). Similar findings were also noticed for the objective measure of internal load (i.e., HR), because heart rate responses were lower within  $CSS_{UV}$  sessions, and this was particular highlighted from the perspective of applied rest period duration. Since *post-hoc*

testing revealed that the *set structure*  $\times$  *rest period duration* interaction was simple, further effect size analyses displayed additional advantage of  $CSS_{UV}$  (i.e., smaller values of HR for both the short- and long-rest sessions). Unfortunately, we failed to find studies that compared effects of different set structures on internal load measures in BWPT. However, Hardee and co-workers (2012b) explored the influences of one standard variant of CSS type (i.e., *basic cluster*) and TSS on the preservation of rating of perceived exertion in resistance power training with the finding that CSS provided significantly lower values of this subjective variable compared to TSS. Further, a couple of studies explored the influence of CSS (i.e., *equal work-to-rest ratio*) and TSS on the subjective measures of internal load in the hypertrophy training (Iglesias-Soler, et al., 2016; Mayo, et al., 2014). In both studies, CSS demonstrated significantly lower values of internal load variables relative to TSS.

Lastly, the main findings of the present study could be advantages of  $CSS_{UV}$  over TSS regarding the performance measure of preservation. Regardless of the applied training volume or rest period duration,  $CSS_{UV}$  allowed overall higher performance compared to TSS sessions (i.e.,  $\%JH_{\max}$  was evidently higher). Furthermore,  $CSS_{UV}$  provided conditions for the preservation of performance during the entire session, while performance in TSS sessions decreased when training volume increased. Also, contrary to the  $CSS_{UV}$ , it seems that TSS is not sensitive in terms of applied rest period duration because longer rest could not provide better performance. To the best of our knowledge, there is only one similar study that monitored  $\%JH_{\max}$  as performance when comparing TSS and CSS (i.e., *rest-redistribution* type applied in standard variant with the fixed number of repetitions between sets) during vertical jump training sessions where body-weight exercise was applied (Moreno, et al., 2014). In the study, CSS allowed greater maintenance of  $\%JH_{\max}$  compared with TSS, which is in line with our findings. Overall, our findings suggest that, when compared to TSS,  $CSS_{UV}$  brings substantial benefits to performance regarding applied training volume and rest period duration.

The present study provides important theoretical implications, since our findings suggest that  $CSS_{UV}$  shows similar characteristics as other variants and/or types of CSS in terms of maintaining power and vertical jump performance, decrease cardiovascular stress and subjects' perceived effort during jumping training session (Haff, et al., 2008; Tufano, Brown, & Haff, 2017). Moreover, this is the first study that explored and confirmed potential advantages of  $CSS_{UV}$  over typical TSS in BWPT; note that we also included training volume and rest period duration as additional independent variables with the purpose to provide more substantial findings.

Further, for the first time we implemented the set of comprehensive indicators for testing our assumptions on CMJ, which is one of the most commonly used test and exercise in athletic training. Namely, along with the direct measure of performance preservation (i.e., %JH<sub>max</sub>), we involved quantitative and qualitative measures of external load and various measures of internal load, such as participants' perceived effort and recovery, as well as heart rate monitoring. Regarding the limitations of the study, it is fair to mention that the absence of post-session recovery data (e.g., muscle soreness as a subjective indicator and/or vertical jump height as an objective indicator) could be potential weakness because the present findings could not be generalized in that important direction.

In conclusion, our study emphasizes the importance of smart designing of set structure in vertical jumping session, since the obtained findings unequivocally suggest that CSS<sub>UV</sub> might be more suitable approach to BWPT design in comparisons to TSS. Namely, the used variant of CSS could be implemented in BWPT based on vertical jump exercises in order to provide: 1) increasing quality of

external load (i.e., allows its superior utilization), 2) decreasing internal load, and 3) preserving task-related performance during the entire training session. Therefore, it appears that the manipulation with the distribution of rest periods within and between sets, recognizable for other types and variants of CSS, along with the manipulation with the number of repetitions within and between sets in the applied variant of CSS, could provide the aforementioned benefits. The present study provides important findings about numerous advantages of CSS<sub>UV</sub> over TSS in terms of external load, internal load and performance during vertical jumping, which is a valid representation for standard BWPT. Hence, it could be concluded that CSS<sub>UV</sub> undoubtedly demonstrated potential for its further application in designing various forms of power training (i.e., ballistic, plyometric or resistance training). It is necessary to further explore its effectiveness with respect to other variants or types of CSS, not only to provide benefits with respect to the acute training effects, but also regarding post-training recovery and possible chronic adaptations.

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