Self-selecting the number of repetitions in potentiation protocols enhances jumping performance

Dello Iacono, Antonio; Beato, Marco; Halperin, Israel

Published in:
International Journal of Sports Physiology and Performance

DOI:
10.1123/ijspp.2019-0926

E-pub ahead of print: 03/12/2020

Abstract

Purpose. To investigate if providing athletes with a choice regarding the number of repetitions to complete in a potentiation protocol would enhance jumping performance compared to protocols in which the number of repetitions is predetermined. **Methods.** Fifteen male basketball players completed four testing sessions separated by 72 hours. On the first session, individual optimum power loads (OPL) in the barbell jump squat were determined. On the following three sessions, athletes completed three sets of three potentiation protocols using OPL jump squats in a partly-randomized order: i) traditional condition included six repetitions per set; ii) self-selected condition included a choice regarding the number of repetition to complete per set; iii) imposed condition included the same number of repetitions per set as the self-selected condition but imposed on the athletes beforehand. Jumping performance was determined as jump squat (JS) test height and measured using a force platform before, 30s, 4 min, and 8 min after completing the protocols. **Results.** The self-selected condition led to superior jumping performance compared to the two other conditions across all post measures ($p<0.05$; range: 0.3-1.3 cm). Compared to the traditional condition, the imposed condition led to superior jumping performance across all post measures (range: 0.2-0.45 cm) although not statistically significant at post 4 min and 8 min. **Conclusions**. Choice provision concerning how many repetitions to complete in a potentiation protocol is a useful performance enhancing strategy. Improved potentiation-fatigue ratio and motivational factors are sought to explain these effects.

Keywords

Autonomy; ballistic exercises; choice provision; explosiveness; jumping

Introduction

Postactivation performance enhanchment (PAPE) refers to a short-term improvement in athletic tasks such as jumping, sprinting and throwing, induced by a previous conditioning activity.[1] The onset and magnitude of PAPE effects are influenced by a number of variables and their interactions.[2] Primarily, the type,[3,4] volume and intensity of the conditioning activity; [5,6] the rest interval between the conditioning activity and the subsequent athletic task;[7] and the individual characteristics of the performer, including gender, strength levels, and training background.[5,8,9] The interactions between these variables result in two concurrent responses arising from PAPE protocols: muscular fatigue and potentiation.[2] At the completion of the conditioning activity, muscular fatigue outweighs potentiation effects, resulting in impaired performance. However, since fatigue dissipates at a faster rate than potentiation, the potentiation effects can be realized at some point during the recovery interval, which enhances performance.[1] The balance between fatigue and potentiation is of paramount importance for successful PAPE protocols implementation, and thus a topic of intensive investigations.

A growing number of studies investigated protocols designed to optimize PAPE effects by manipulating PAPE related variables. However, the vast majority of them are commonly designed using predetermined and non-personalized loads and volumes.[1,5] Accordingly, it can be assumed that such general routines could induce too much fatigue for some, and under potentiate others. Although mean effects can be observed and acted upon, a more individualized approch could optimize the releationship between fatigue and potentiation. In support of this rationale, two recent studies observed that PAPE effects can be enhaced by using optimal power load (OPL) in the conditioning activity exercise, tailored per participant based on individual mechanical profiles.[4,10] Whereas the OPL approach is unfolding as a successful strategy to individualize the load variable of PAPE protocols, a method that individualizes the volume component needs to be developed.

One viable strategy to individualize the volume in the conditioning activity of PAPE protocols is by allowing participants to choose when to terminate a set based on their understanding of the task and its requirements. Allowing people to act autonomously by making choices is an evidence based powerful coaching strategy.[11-17] Studies from exercise psychology and motor learning have shown that by providing choices regarding exercise related variables, participants improve motor learning,[12] report greater enjoyment and motivation,[13] and exhibit greater adherence levels to an exercise program.[14] Recently, the effects of choice provision have been also studied in relation to physical performance outcomes that require maximal force production.[15,18] For example, Halperin et al.,[16] reported that providing competitive kickboxers with choices regarding the order of the delivered punches, led to immediate increases in punching impact forces and velocity. Whereas the underpinning mechanisms accounting for these effects are not fully agreed upon, neuroscience[17] and psychological research[19] points to motivational reasons being the main pathway explaining the performance enhancing effects. In view of the accumulating evidence, investigating if choice provision strategy can be implemented in PAPE protocols is a worthwhile endeavour.

The aims of this study are threefold. First, we aim to investigate if providing athletes with a choice on how many repetitions to complete in the conditioning activity would improve subsequent athletic performance compared to a traditional PAPE inducing condition, in which the volume is fixed. Second, assuming that the choice condition should enhance performance, we aim to examine its underlying cause. That is, will performance improve due to the self-selected volume leading to enhaced fatigue-potention relationship, or the fact that participants will be allowed to choose and act autonomously, will increase motivation and drive to complete the task in a superior manner? To an extent, it is possible to answer this question by including a third condtion in which the exact same volume used in the choice condtion will be subsequently and unknowingly imposed on the participants. Hence, in a third condition, participants will be repeating the exact same condition as the self-selected one, but with the volume being imposed by a researcher. For this, trained athletes will complete three PAPE protocols using jump squats with OPL as the conditioning activity: traditional, self-selected, and imposed conditions, with the outcome being squat jump performance.

Methods

Subjects

A convenience sample of fifteen male professional basketball players (age 24.3 [SD: 4.2] years; height 188.1 [5.2] cm; body mass 87.7 [7.3] kg) volunteered to participate in the study. The players had at least five years (range: 5-9) of high-level practice and five years (range: 5-9) of resistance training experience. All subjects had also at least two years (range: 2-5) of resistance training experience involving OPL methodologies. Written informed consent was obtained after the subjects received an oral explanation of the purpose, benefits, and potential risks of the study. All procedures were conducted in accordance with the Helsinki Declaration and approved by the Institution's Ethics Committee.

Design

A randomized cross-over design was used to compare the effects of three PAPE protocols implementing jump squats loaded with OPL as the conditioning activity but executed using different configurations: i) traditional, in which the sets and repetitions completed are aligned with the contemporary PAP literature, [3-6,8-10] ii) self-selected, in which subjects were allowed to choose the number of repetitions completed in each set, and iii) imposed, in which the number of repetitions completed matched those of the self-selected condition, but imposed on subjects prior to the beginning of the session, rather than self-selected during each set. The effects of the three protocols were compared on subsequent vertical jump performance asssessed by the squat jump test. One week prior the study commencement, subjects completed two familiarization sessions during which they were provided with an explanation of the study procedures, and performed the PAPE protocol using the traditional configuration. Then, three experimental sessions were completed, each including: a standardised warm up, baseline squat jump assessment, one of the three conditions, and squat jump reassessment after 30 s, 4, and 8 min of passive recovery (see Figure 1 for overview). The order in which the protocols were completed was counter-balanced and partially determined by block randomisation (www.random.org) so that the imposed protocol always followed the self-selected condition. All subjects performed the three experimental trials within two weeks and with 72-96 hours apart from each other. The protocols were executed according to standard procedures previously reported.[10]

*****Figure 1 about here*****

Optimum power load assessment

One week prior to the familiarization sessions, the OPL in the jump squat exercise were assessed for each athlete. First, the subjects performed an 8 min general warm up consisting of running drills and dynamic mobilization exercises. Then, jump squat warm up sets with progressively heavier loads were performed. The same instructions recently described by Dello Iacono et al.,[10] were used for the jump squat execution. The OPL were assessed following the protocol described by Loturco et al.,[20] on a Smith machine (Technogym

Equipment, Italy). The OPL were determined as the jump squat with the highest mean propulsive power values measured during the successive trials, and then used to design the PAPE protocols. The mean propulsive power measures were collected using a linear encoder (Chronojump, Barcelona, Spain) sampling at 1000 Hz and fixed to the bar of the Smith machine, and computed using the commercial software provided by the manufacturer in conjunction with the device. Finally, body mass normalized mean propulsive power outputs (Relative power = W/kg) were used for data analysis purpose. The normalized mean propulsive power scores measured during the OPL assessment were 9.6 (1.3) W/kg.

Vertical jump assessment

Vertical jump capability was assessed by a squat jump test following a standard protocol. The SJs vertical ground reaction forces (GRF) outputs were collected by stationary force plate (Kistler Biomechanics, Winterthur, Switzerland). Sampling frequency was set at 500 Hz and the signal was electronically processed and amplified by a Kistler amplifier (model No 9681A). The GRF data were used to define some key instants of the SJ such as: (i) start – defined as the instant in which the GRF went above a threshold value of 5% relatively to the subjects' body mass, (ii) takeoff - defined as the instant in which the GRF went below the threshold value of 0 N. The vertical jump performance (cm) was determined by the vertical velocity of the center of mass at takeoff calculated by double integrating the vertical GRF through the impulse-momentum method.[21] Both the peak vertical GRF outputs (GRF_{peak}) and the relative vertical impulse, determined from the force-time curves as the ratio between the total impulse produced during the SJ and the impulse due to body mass alone were collected. Subjects completed a baseline assessment consisting of three SJs (the best result used for the analysis) with approximately 45 seconds rest in-between while only a single SJ trial was repeated per each post-PAPE time point. A single researcher administered all the tests thus minimizing potential effects due to the provided instructions.

Postactivation performance enhancement protocols

All three PAPE protocols consisted of three sets of jump squats loaded with OPL. In the traditional protocol subjects completed six repetitions across the three sets. In the self-selected protocol, subjects completed as many repetitions as they felt fit to minimize fatigue and maximize subsequent performance in each set. The number of completed repetitions was determined during each ongoing set. In the imposed protocol, subjects completed the same number of repetitions as in the self-selected condition, but this time absent of choice. That is, subjects were told how many repetitions they would need to complete by the researcher, and unknowingly to them, the numbers were identical to those they completed in the self-selected condition. The rest period between sets in all protocols was 2 minutes. Subjects were asked to assume the same position as the one described for the OPL assessment procedures and instructed to focus on moving the bar as fast and as forcefully as possible by promoting an external focus of attention to elicit the greatest mechanical outputs.[22]

Statistical Analysis

All data are presented as means ± standard deviation (SD) and confidence interval (95% CI). Normality of the absolute data was investigated using the Shapiro-Wilk test, and skewness and kurtosis values smaller than 2 served as indication of normality.[23] The intra-day reliability of the three baseline SJs in day 2, day 3 and day 4 was examined using the Coefficient of Variation (both absolute and percent). A CV< 5% is considered a cut-off value for high reliability.[24] The inter-day reliability of the highest baseline SJs in day 2, day 3 and day 4 was assessed by calculating the Intra-class Correlation Coefficient ($ICC_{3,1}$). Values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.9 were interpreted as indicative of poor, moderate, good, and excellent reliability, respectively.

To compare the effects between the PAPE protocols, a two-way repeated measures Analysis of Variance (ANOVA) of the absolute scores across all time points, was used (three conditions x four time points [baseline, post 30 s, post 4 min and post 8 min]). This analysis was conducted for the following variables: jump height, impulse, GRF_{peak}. Additionally, the primary outcome, SJ height, was also analyzed by comparing the change scores of the post-pre differences between conditions. That is, the post-tests values of each participant were subtracted from the baseline values within a given condition (e.g., post 30 s – baseline). Then, these differences were compared between conditions using a two-way repeated measures ANOVA (three conditions x three time points [post 30 s, post 4 min and post 8 min]). This allowed to examine differences between conditions while also accounting for baseline differences. The individual athletes' power outputs monitored during each PAPE protocol were expressed as percentage of the relative mean propulsive power recorded during the OPL assessment to provide an estimate of fatigue elicited by the three protocols. Differences between conditions were analyzed using a one-way ANOVA. Significance was at $p< 0.05$. 95% confidence intervals (CI) are reported alongside the p values to allow for a better qualitative interpretation of the data.[25,26] If significant main effects or interactions were identified then post hoc analyses were conducted using the Holm-Bonferroni correction for the p values and CI.[27] Finally, differences in the repetitions completed between the three conditions were analyzed using a one-way non-parametric ANOVA (Kruskal-Wallis *H* test) due to the violation of the normality distribution assumption. All statistical analyses were conducted using Jamovi (version 1.0.5.0) and Excel sheets.

Results

The duration of the protocols, including the rest intervals and duration of the sets, was 5 minutes for all the conditions. All data presented normal distribution except for the conditioning volumes (number of sets by number of repetitions) of the three experimental protocols. The absolute scores of the individual intra-day variation between the three baseline SJs in day 2, 3 and 4 were ≥ 0.4 cm; the CV% in day 2 and 3 of the intra-day SJs were ≥ 0.8%; and the ICC scores between the highest baseline SJs in day 2, day 3 and day 4 were 0.95. These results demonstrate high inter- and intra-day reliability.

First, a significant main effect for time was observed for absolute jump height ($F_{(6, 84)} = 30.7$, $p < 0.001$). Across all conditions a similar pattern emerged, with jump height reduced by 1cm (95% CI: 0.7, 1.2; $p < 0.001$) at post 30 s compared to baseline, but then improved by 1.7cm (95% CI: 1.4, 1.9; $p < 0.001$) and 1.8cm (95% CI: 1.6, 2.0; $p < 0.001$) at post 4 min and post 8 min, respectively, compared to baseline. Second, statistically significant interactions were identified between conditions and time for absolute jump height ($F_{(6, 84)} = 30.7$, $p < 0.001$), impulse ($F_{(6, 84)} = 31.5$, $p < 0.001$), GRF_{peak} ($F_{(3, 38)} = 12.9$, $p < 0.001$), and for the change scores in SJ height ($F_{(3, 45)} = 4.2$, $p = 0.006$), all showing that the self-selected condition led to more favorable responses compared to the traditional and imposed conditions, and that the imposed condition tended to lead to more favorable responds compared to the traditional (See Table 1 for descriptive statistics, corrected p values and 95% CI). The Kruskal-Wallis *H* test revealed significant differences for conditioning volumes between both the self-selected and imposed conditions and the traditional one ($\chi^2 = 31.3$, $p < 0.001$). The number of repetitions completed during the self-selected and the matched imposed protocols were 13.4 (0.98) and resulted in the following set configuration: 3 sets of 4.9 (0.26), 4.5 (0.52), 3.9 (0.48).

*****Table 1 and Figure 2 about here*****

Discussion

In this study we examined if providing subjects with a choice regarding the number of repetitions completed during a PAPE protocol will enhance vertical jump performance. Subjects completed three PAPE protocols: traditional, in which the number of repetitions in the conditioning activity was fixed; self-determined, in which the number of repetitions in the conditioning activity was self-selected; imposed, in which the number of repetitions matched the self-selected condition, but imposed by a researcher unknowingly to the subjects. Across all three conditions, comparable time-course effects relative to baseline were found, with initial reductions in SJ heights at post 30 s, followed by enhancements at post 4 and post 8 min. However, differences between conditions were observed. First, compared to the two other conditions, the self-selected protocol led to superior performance across all post measures. Second, the imposed condition enhanced performance compared to the traditional condition. These findings have practical application and can be largely explained by mechanical and motivational pathways.

The time-course effects induced by all PAPE protocols are consistent with the PAPE literature[2,4,6,9,10] reporting transitional fatigue at the PAPE protocol completion, followed by potentiation after approximately 4 min of rest. The superior jumping performance observed in the self-selected condition, and partly in the imposed condition, can be explained by the individually selected repetitions which led to a more favorable fatigue-potentiation balance (Figure 2). This assumption is supported by two main observations. First, higher relative mean propulsive power values were observed during the self-selected protocol compared to both the traditional and imposed conditions (5.7% and 3.5%, respectively). Second, advantageous mechanical responses were associated to the SJ at the post-tests following the self-determined protocol (Table 1). Specifically, subjects were able to generate greater impulse outputs that, coupled with higher GRF_{peak}, indicate enhanced neuromuscular efficacy.[28] Hence, in view of the mechanistic perspective, it seems that subjects were able to identify the number of repetitions required to elicit a better relationship between fatigue and potentiation. This is contrast to the traditional condition designed with a fixed number of repetitions, which does not allow for individual consideration of this balance. While a fixed number of repetitions in PAPE protocols may lead to enhanced performance at the group level, this strategy fails to account for ongoing and unfolding individual abilities that may fluctuate between and within individuals on a daily and even momentary basis.

Whereas the mechanical perspective can assist explaining the differences between the self-selected and imposed conditions to the traditional condition, it cannot explain the differences between the former two. Since subjects under both conditions completed the same exact protocol, the superiority of the self-selected condition is likely the result of motivational aspects stemming from subject's ability to choose. According to established psychological theories,[19,29] people strive to act autonomously by exerting control over their behaviours, environments, and goals. Granting people with choice options increases perception of autonomy and motivation to perform.[17,19,29,32] Research from a broad range of disciplines including educational, workplace, health and human movement domains, show that choice provision is effective in improving a wide range of outcomes.[29-31] Whereas in human movement sciences choice provision has been mostly studied in the motor learning domain,[19] recent studies report that choice provision can also enhance acute physical performance.[15,16,32] For example, Halperin et al.,[16] reported that competitive kickboxers punched 3-10% harder and 6-11% faster when granted with choice about the order of punches to be delivered, compared to a condition in which the punches order was determined by a coach. Confirming these effects, Iwatsuki et al.,[15] reported that maximal handgrip strength was better maintained when recreationally trained subjects choose the order of the hands in which the contractions were completed (dominant vs. nondominant). Such findings suggest that choice provision can positively affect immediate physical performance. The results of the current study are aligned with these findings and support the use of autonomy supportive strategies also to acutely improve athletic performance.

This study has a number of limitations worthy of discussion. First, the study design was not fully randomized considering that the imposed condition always followed the self-determined one. Therefore, an order effect inherent to this sequence may have somehow affected the results. Second, we did not conduct a power analysis to determine the sample size. For practical reasons, the sample was limited to a single team of athletes which limits our ability to generalize to other populations. To partly overcome the limitations associated with smaller sample sizes, we implemented a within-subject design and controlled for a large number of confounding variables, such as diet, time of the day, baseline warm up and more. Third, due to logistical constraints, the potentiation effects of the three protocols were investigated only on vertical jump capability which was assessed in a lab-based environment. This fact narrows the ability to generalize the results from this study to more representative situations involving jumps during a basketball game. Future studies are warranted to investigate whether granting athletes with more choices, such as the conditioning activity type, conditioning activity load, protocol configuration and rest interval may lead to comparable or even better PAPE effects.

Practical Applications

Coaches should consider granting athletes with individual choices about the training volumes to be used for PAPE protocols aimed at enhancing vertical jump performance. Choice provision seems to exploit the PAPE effects by increasing the motivational drive, by reducing fatigue and by enhancing the mechanical responses underpinning jumping performance. In view of the performance augmentations observed in this study coupled with the broad supporting research, choice provision coaching strategies should likely be used more often and more explicitly by strength and conditioning coaches.

Conclusion

We found that allowing athletes to choose how many repetitions to complete during a PAPE protocol led to greater potentiation effects compared to two other conditons. The first was a traditional PAPE condition, in which the volume was fixed, and the second was a matched repetition condition, in which subjects completed the same number of repetitions as they did in choice condition, but with the repetitions number imposed by the researcher. This superior performance under the choice condition is likely due to enhanced motivation stemming from subjects' ability to choose, and by optimizing the fatigue-potentiating relationship within sets. These results point to the importance of individualized prescription approaches in PAPE protocols, with choice provision being one strategy to achieve this goal.

References

1. Blazevich AJ, Babault N. Post-activation Potentiation (PAP) versus Post-activation Performance Enhancement (PAPE) in Humans: Historical Perspective, Underlying Mechanisms, and Current Issues. Frontiers in Physiology. 2019;10:1359.
2. Tillin NA, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. Sports medicine (Auckland, NZ). 2009;39(2):147-166.
3. Dello Iacono A, Padulo J, Seitz LD. Loaded hip thrust-based PAP protocol effects on acceleration and sprint performance of handball players. Journal of sports sciences. 2018;36(11):1269-1276.
4. Dello Iacono A, Seitz LB. Hip thrust-based PAP effects on sprint performance of soccer players: heavy-loaded versus optimum-power development protocols. Journal of sports sciences. 2018;36(20):2375-2382.
5. Wilson JM, Duncan NM, Marin PJ, et al. Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. Journal of strength and conditioning research. 2013;27(3):854-859.
6. Dello Iacono A, Martone D, Padulo J. Acute Effects of Drop-Jump Protocols on Explosive Performances of Elite Handball Players. Journal of strength and conditioning research. 2016;30(11):3122-3133.
7. Dello Iacono A, Martone D, Milic M, Padulo J. Vertical- vs. Horizontal-Oriented Drop Jump Training: Chronic Effects on Explosive Performances of Elite Handball Players. Journal of strength and conditioning research. 2017;31(4):921-931.

8. McBride JM, Nimphius S, Erickson TM. The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. Journal of strength and conditioning research. 2005;19(4):893-897.

9. Seitz LB, Haff GG. Factors Modulating Post-Activation Potentiation of Jump, Sprint, Throw, and Upper-Body Ballistic Performances: A Systematic Review with Meta-Analysis. Sports medicine (Auckland, NZ). 2016;46(2):231-240.

10. Dello Iacono A, Beato M, Halperin I. The Effects of Cluster-Set and Traditional-Set Postactivation Potentiation Protocols on Vertical Jump Performance. International journal of sports physiology and performance. 2019:1-6.

11. Halperin I, Wulf G, Vigotsky AD, Schoenfeld BJ, Behm DG. Autonomy: a missing ingredient of a successful program? Strength & Conditioning Journal. 2018;40(4):18-25.

12. Wulf G, Iwatsuki T, Machin B, Kellogg J, Copeland C, Lewthwaite R. Lassoing Skill Through Learner Choice. Journal of motor behavior. 2018;50(3):285-292.

13. Lewthwaite R, Chiviacowsky S, Drews R, Wulf G. Choose to move: The motivational impact of autonomy support on motor learning. Psychonomic bulletin & review. 2015;22(5):1383-1388.

14. Silva MN, Markland D, Carraca EV, et al. Exercise autonomous motivation predicts 3-yr weight loss in women. Medicine and science in sports and exercise. 2011;43(4):728-737.

15. Iwatsuki T, Abdollahipour R, Psotta R, Lewthwaite R, Wulf G. Autonomy facilitates repeated maximum force productions. Human movement science. 2017;55:264-268.

16. Halperin I, Chapman DW, Martin DT, Lewthwaite R, Wulf G. Choices enhance punching performance of competitive kickboxers. Psychological research. 2017;81(5):1051-1058.

17. Leotti LA, Delgado MR. The inherent reward of choice. Psychological science. 2011;22(10):1310-1318.

18. Halperin I, Chapman DW, Martin DT, Abbiss C, Wulf G. Coaching cues in amateur boxing: An analysis of ringside feedback provided between rounds of competition. Psychology of Sport and Exercise. 2016;25:44-50.

19. Wulf G, Lewthwaite R. Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. Psychonomic bulletin & review. 2016;23(5):1382-1414.

20. Loturco I, Nakamura FY, Tricoli V, et al. Determining the optimum power load in jump squat using the mean propulsive velocity. PloS one. 2015;10(10):e0140102.

21. Moir GL. Three different methods of calculating vertical jump height from force platform data in men and women. Measurement in Physical Education and Exercise Science. 2008;12(4):207-218.

22. Wulf G. Attentional focus and motor learning: a review of 15 years. International Review of sport and Exercise psychology. 2013;6(1):77-104.

23. Leech NL, Onwuegbuzie AJ. A Call for Greater Use of Nonparametric Statistics. 2002.

24. Hopkins WG. Measures of reliability in sports medicine and science. Sports medicine (Auckland, NZ). 2000;30(1):1-15.

25. Cumming G. The new statistics: Why and how. Psychological science. 2014;25(1):7-29.

26. Dragicevic P. Fair statistical communication in HCI. In: Modern Statistical Methods for HCI. Springer; 2016:291-330.

27. Ludbrook J. Multiple inferences using confidence intervals. Clinical and Experimental Pharmacology and Physiology. 2000;27(3):212-215.

28. Winter EM. Jumping: Power or impulse? Medicine & Science in Sports & Exercise. 2005;37(3):523.

29. Sanli EA, Patterson JT, Bray SR, Lee TD. Understanding Self-Controlled Motor Learning Protocols through the Self-Determination Theory. Frontiers in psychology. 2012;3:611.

30. Patall EA, Cooper H, Robinson JC. The effects of choice on intrinsic motivation and related outcomes: a meta-analysis of research findings. Psychological bulletin. 2008;134(2):270-300.

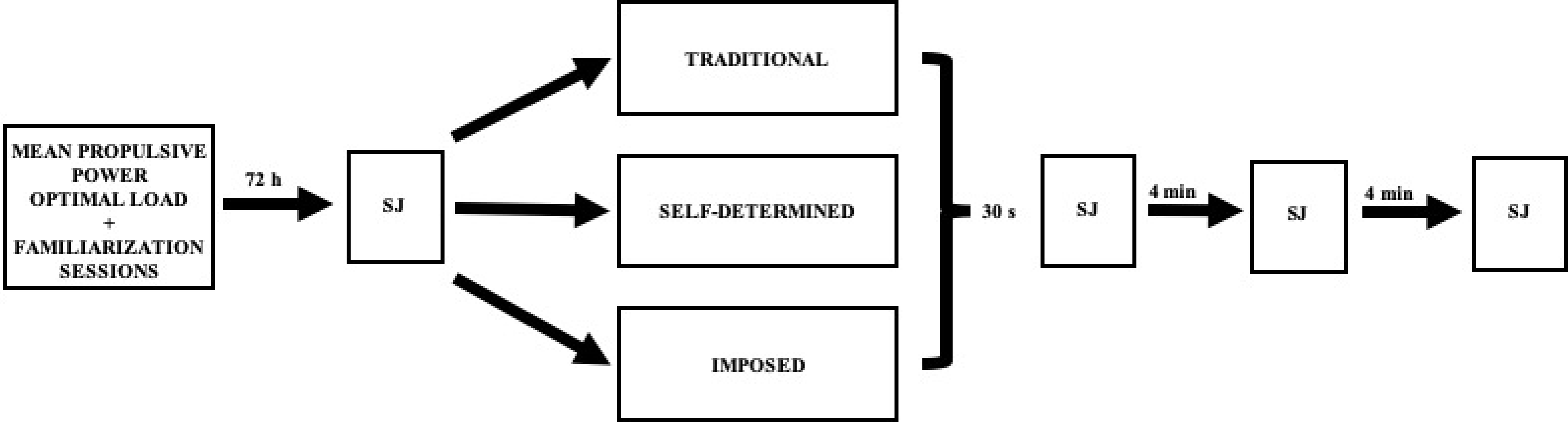
31. Teixeira PJ, Carraca EV, Markland D, Silva MN, Ryan RM. Exercise, physical activity, and self-determination theory: a systematic review. The international journal of behavioral nutrition and physical activity. 2012;9:78.

32. Wulf G, Freitas HE, Tandy RD. Choosing to exercise more: Small choices increase exercise engagement. Psychology of Sport and Exercise. 2014;15(3):268-271.

Figure Captions

Figure 1. Schematic representation of the study design. SJ: squat jump

Figure 2. Illustrates the change scores in the three PAPE conditions relative to baseline performance represented by the dashed horizontal line. Dots, squares and triangles denote individual scores.


MEAN PROPULSIVE POWER OPTIMAL LOAD + FAMILIARIZATION SESSIONS
72 h
SJ
TRADITIONAL
SELF-DETERMINED
IMPOSED
30 s
SJ
4 min
SJ
4 min
SJ

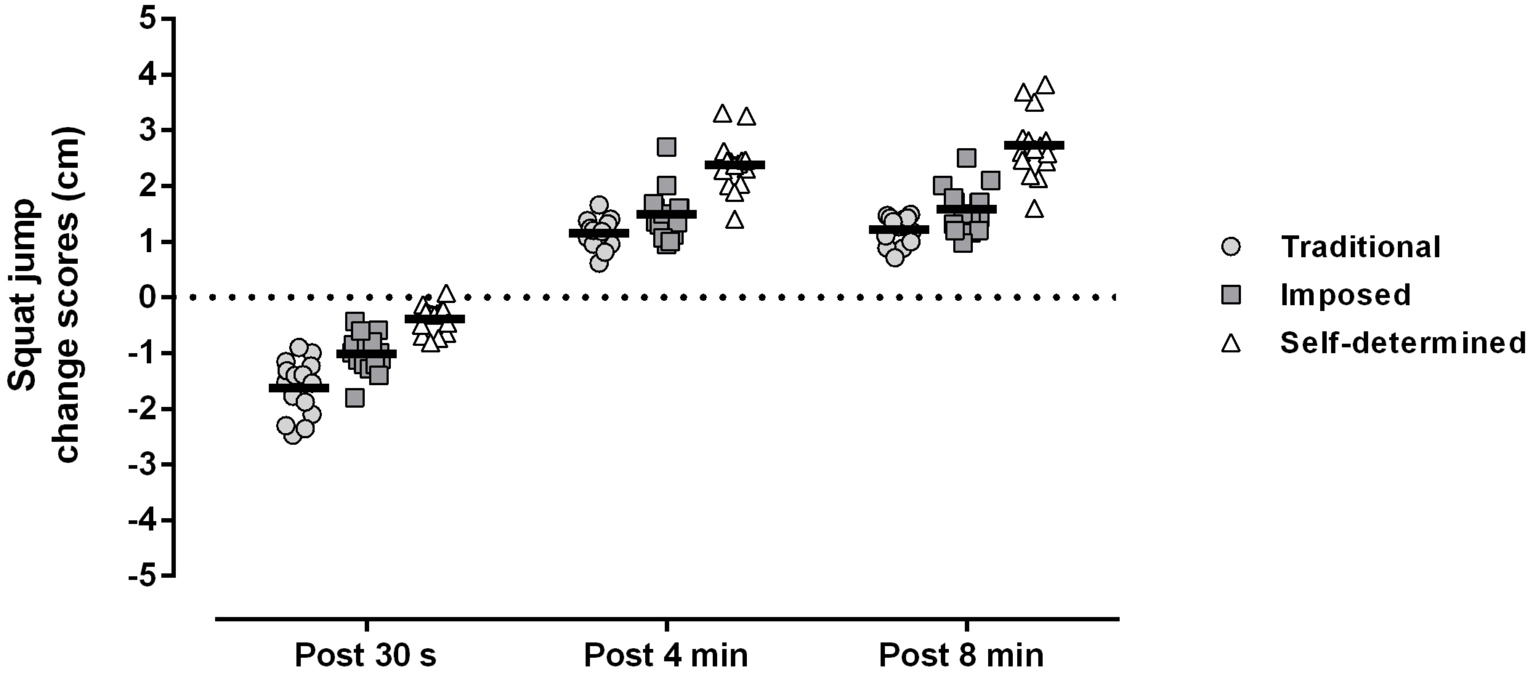

Squat jump
change scores (cm)
5
4
3
2
1
0
-1
-2
-3
-4
-5
Post 30 s
Post 4 min
Post 8 min
Traditional
Imposed
Self-determined

Table 1. Descriptive (mean ± SD) and inferential (95% CI and p values) statistics of all variables, across all time points, for all conditions.

	Time points			
	Baseline	**Post-30 s**	**Post-4 min**	**Post-8 min**
SJ absolute values (cm)				
Traditional	45±7.8	43.4±7.6	46.1±7.8	46.2±7.9
Self-determined	44.7±8.1	44.3±8	47.1± 8.5	47.5± 8.5
Imposed	44.8±7.4	43.8±7.5	46.3± 7.6	46.4± 7.7
SJ change scores values (post-tests minus pre-test values)				
Traditional		-1.62±0.5	1.15±0.26	1.21±0.24
Self-determined		-0.39±0.25	2.38±0.48	2.73±0.59
Imposed		-1.01±0.35	1.49±0.44	1.58±0.41
SJ mean difference				
Traditional vs Self-determined		-0.97 (-1.83, -0.1) | p = 0.021	-0.96 (-1.84, -0.09) | p = 0.024	-1.25 (-2.2, -0.31) | p = 0.008
Traditional vs Imposed		-0.45 (-0.82, -0.08) | p = 0.008	-0.19 (-0.42, 0.04) | p = 0.103	-0.21 (-0.51, 0.09) | p = 0.228
Self-determined vs Imposed		0.51 (-0.2, 1.22) | p = 0.188	0.78 (-0.21, 1.76) | p = 0.16	1.04 (0.05, 2.02) | p = 0.035
SJ change scores (cm) between conditions				
Traditional vs Self-determined		-1.24 (-0.81, -1.66) | p = 0.006	-1.21 (-1.15, -1.27) | p = 0.007	-1.51 (-1.02, -1.99) | p = 0.008
Traditional vs Imposed		-0.62 (-0.27, -0.97) | p = 0.027	-0.33 (-0.15, -0.51) | p = 0.002	-0.37 (-0.14, -0.6) | p = 0.002
Self-determined vs Imposed		0.62 (0.28, 0.96) | p = 0.004	0.88 (0.57, 1.19) | p = 0.004	1.14 (0.72, 1.56) | p = 0.005
GRF_{peak} absolute values (N)				
Traditional	1585±195	1523±190	1630±192	1636±194
Self-determined	1590±194	1568±191	1687±194	1699±193
Imposed	1586±203	1549±198	1641±209	1648±208
GRF_{peak} mean difference				
Traditional vs Self-determined		-45.2 (-67.6, -22.9) | p = 0.008	-57.6 (-88.4, -26.8) | p = 0.007	-62.9 (-100, -25.6) | p = 0.006
Traditional vs Imposed		-25.4 (-52.1, 1.4) | p = 0.068	-11 (-33.6, 14.6) | p = 0.602	-11.6 (-36.7, 13.6) | p = 0.342
Self-determined vs Imposed		19.9 (-7, 46.7) | p = 0.192	46.6 (4.5, 87.7) | p = 0.025	51.3 (3.8, 98.9) | p = 0.03
Impulse absolute values ($N \cdot s^{-1}$)				
Traditional	2.58±0.27	2.48±0.27	2.64±0.27	2.65±0.27
Self-determined	2.59±0.29	2.56±0.28	2.72±0.3	2.75±0.3
Imposed	2.54±0.21	2.48±0.21	2.63±0.21	2.63±0.21
Impulse mean difference				
Traditional vs Self-determined		-0.08 (-0.14, -0.02) | p = 0.063	-0.08 (-0.15, -0.02) | p = 0.006	-0.1 (-0.04, -0.16) | p = 0.008

Traditional vs Imposed	0 (-0.04, 0.03) | p = 0.889	0.01 (-0.04, 0.06) | p = 0.998	0.01 (-0.04, 0.07) | p = 0.999
Self-determined vs Imposed	0.08 (0.11, 0.14) | p = 0.016	0.1 (0.21, 0.17) | p = 0.01	0.11 (0.03, 0.23) | p = 0.007

SJ: squat jump; GRF_{peak}: peak ground reaction forces; CI: confidence intervals