THE EFFECT OF A 10 SECOND ISOMETRIC SQUAT ON LOWER BODY POTENTIATION IN A PRACTICAL SETTING
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Abstract

A short bout of high intensity exercise has been shown to confer performance benefits for a short period of time afterwards. These benefits manifest as a balance between fatigue and potentiation. The time at which maximal performance is produced is highly individual as recovery time varies. Many current potentiation protocols are difficult to utilise in a practical setting due to equipment or time constraints. The aim of the current study was to evaluate the effect of a ten second isometric squat on peak power output and to assess the optimal recovery time required for maximal performance. Ten premier league university rugby players will perform three countermovement jumps at six, nine, twelve and fifteen minutes after carrying out the isometric squat by pushing against a fixed bar set up in a smith machine. The best countermovement jump at each interval will be used to determine peak power output. Statistical analysis revealed an insignificant trend for decrease in power at six minutes followed by an insignificant increase at nine, twelve and fifteen minutes compared to baseline. Individual analysis of the raw data for each subject found a significant difference between baseline scores and maximal peak powers achieved regardless of time interval (p = 0.002). Five subjects scored their maximal values at 12 minutes, two achieved maximal values at 9 minutes and two achieved maximal values at 15 minutes. One subject did not experience an increase in power beyond baseline. We concluded that peak power output can be increased by performing a 10 second isometric squat prior to performance. However, the time of maximal peak power output, therefore peak performance, was highly individualised and would need to be evaluated on an individual basis before it could be used in a practical setting.
CHAPTER I
INTRODUCTION
1.0 Introduction

1.1 Definition of Postactivation Potentiation

Postactivation potentiation (PAP) is a phenomenon that has only come to light fairly recently. It is believed to cause an increased mechanical output in the muscle after an initial fatiguing stimulus (preload stimulus). This can refer to an electrical or exercise based stimulus. In practical terms however, potentiation refers to an exercise stimulus such as a series of heavy squats that will cause an acute increase in performance in an associated performance measure. Performance measures are usually short lasting explosive movements such as weightlifting, sprints or jumps.

1.2 Complex Training

There have been attempts to use this potentiation phenomenon in both acute and chronic phases. Both involve pairing two biomechanically similar exercises; an explosive and a heavy resistance exercise (HRE) into a complex pair (Hodgson et al., 2005). The acute phase involves improving performance for a short period. The chronic phase, also known as ‘Complex Training’ looks at long-term improvements and aims to capitalise on the increase in performance afforded by the HRE to allow improved training effect from the plyometric exercise. Over many sessions this is theorised to be more effective than traditional training, where power and strength techniques are carried out in separate sessions, due to the higher intensity of complex training (Robbins, 2005). There is very little evidence regarding this form of long term training and much more research has to be done before it becomes the mainstay of power and strength programmes. A review paper has stated that minimally, complex training is an efficient way of organising a workout and suggests that it is equally effective and in some cases superior to other forms of combined training (Ebben, 2002).

1.3 Aim

The purpose of this study is to evaluate a potentiation protocol that would be feasible in a sports setting and to find the optimal recovery time for this particular protocol. No other studies in the current literature have explored postactivation potentiation in this way.
CHAPTER III
METHODOLOGY
3.0 METHODOLOGY
The study had a within-subject design, thus eliminating error associated with individual variances. Each subject attended the laboratory on two occasions. The purpose of the first session was familiarisation with the equipment and technique required for the ‘test’ session. A qualified gym instructor gave instruction and advice as necessary.

3.1 Subjects
Written informed consent was obtained from 10 male University Premier League rugby players and the study was carried out within the rugby season. Ethical approval was gained from the in-house ethics committee. None of the subjects had any long-term illnesses and were not carrying any injuries that would affect performance in the testing. Subjects were recruited on the basis that they had a minimum one year experience in weight lifting, in particular the back squat exercise and able to demonstrate correct technique for this exercise. Subjects unable to demonstrate correct technique as assessed by a gym instructor were excluded.

Table 3. Physical characteristics of the subjects

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>91 ± 11</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>184 ± 7</td>
</tr>
<tr>
<td>Age (y)</td>
<td>22 ± 0</td>
</tr>
</tbody>
</table>

3.2 Experimental procedures
Regardless of experience the subjects were required to attend a familiarisation session before the experiment. During the familiarisation session each subject was coached and required to demonstrate competence in the both back squats and counter movement jumps. It also enabled the subjects to practise the counter movement jump used for power testing. The single test session was performed a minimum of 48 hours following the familiarisation. The subjects reported to the
laboratory for testing having refrained from alcohol, caffeine and heavy exercise in the previous 24 hours. Body mass and stature were measured.

Prior to the testing session, all subjects completed a standardised warm up. It consisted of 5 minutes of light intensity cycling on a cycle-ergometer, followed by exercise specific dynamic stretching (3 sets of 10 reps body weight squats) aimed at warming the musculature associated with back squatting.

After the warm-up was completed, the subjects carried out a ‘baseline’ set of three counter movement jumps with a pole rested across their shoulders. The pole would later be used to attach the Ballistic Measurement System. After a recovery period of 10 minutes had elapsed, the potentiation protocol was carried out, which consisted of an isometric squat in the half squat position. Thighs were angled 45°, half way between vertical and parallel to the ground. As the bar was fixed by inverting the safety pins in the smith machine, the level of bar and therefore the half squat was set to the nearest pin setting (Figure 4).

![Figure 1. Schematic of Smith Machine and safety pins](image)

This isometric exercise lasted for 10 seconds and required maximal effort from the subject. Verbal encouragement was given in form of a countdown.

Following the potentiation protocol a set of 3 CMJ were performed at 6, 9, 12 and 15 minutes. Room temperature was between 17°C and 19°C throughout the experimental period. Verbal encouragement and instruction was given throughout to ensure maximal performance.
3.3 Measurements
Peak power output was measured during the counter movement jumps performed with a pole across the shoulders. The subject was instructed to jump as high as possible, maintaining a firm grip on the pole. The subject was then required to reset before the next rep, completing 3 repetitions per set within a 15 second testing period.

Bar displacement data was collected using a Ballistic Measurement System (BMS: www.fittech.com.au) attached to the pole, which was resting across the subjects shoulders. The system comprises a cable-extension potentiometer (distance transducer) that produces a variable-voltage output in relation to the extension of the cable. The USB data collection interface, and custom software (400Hz sampling rate) accurately measured the vertical movement of the athlete. Velocity, acceleration, force and power were then calculated. The accelerometer was re-calibrated using a metre rule at the beginning of each testing session.

3.4 Statistical Analysis
Normality was assumed and all data were expressed as the mean ± SD unless stated otherwise. Statistical analysis was carried out on SPSS using a repeated measures analysis of variance (ANOVA) to determine whether there was a difference in PPO between baseline and 6, 9, 12 and 15 minutes during a CMJ. This was followed by a paired t-test for individual data. Statistical significance was declared at p ≤ 0.05. A Pearson correlation was carried out between maximal PPO and percentage increase in power from baseline to maximal PPO. Null hypothesis one is that there is no difference between the mean PPO at baseline and 6, 9, 12 and 15 minutes after a 10 second isometric squat. Null hypothesis two is that there is no difference between the individual PPO at baseline and the maximal PPO achieved by each individual subject.
CHAPTER IV
RESULTS
4.0 Results

4.1 Mean Peak Power Output

An ANOVA_{RM} between PPO at each interval revealed no significant time effect (p = 0.193) in the data. There were no significant increases or decreases in PPO within the timeframe that measurements were carried out. However, a non-significant trend was observed. The power dropped between baseline and 6 minutes (5,475 ± 2,286 W vs. 5,198 ± 1,964 W, p = 0.345). Power then rose from 6 minutes to peak at 9 minutes (5,198 ± 1,964 W vs. 5,754 ± 2,600, p = 0.099), before dropping at 12 minutes (5,754 ± 2,600 W vs. 5,564 ± 2,040 W, p = 0.570). It finally rose from 12 to 15 minutes (5,564 ± 2,040 W vs. 5,732 ± 2,142 W, p = 0.478). These changes are summarised in figure 2.

![Figure 2. Line graph showing changes in power along the time intervals](image)

As the standard deviation was so large, the percentage change in power from baseline was worked out for each time interval, these are presented in figure 3.

None of the individual differences between baseline and the various time intervals were significant as shown in table 4.
Figure 3. Bar chart showing percentage change at each time interval from baseline.

Table 4. P-Values for changes in PPO from baseline to the various time intervals

<table>
<thead>
<tr>
<th>Time Intervals</th>
<th>P Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 min</td>
<td>0.345</td>
</tr>
<tr>
<td>9 min</td>
<td>0.094</td>
</tr>
<tr>
<td>12 min</td>
<td>0.773</td>
</tr>
<tr>
<td>15 min</td>
<td>0.325</td>
</tr>
</tbody>
</table>

4.2 Maximal Peak Power Output - Paired T test

As the ANOVA$_{RM}$ showed no significant difference, further analysis was carried out. The mean ($\pm$ sd) baseline PPO was 5475 ($\pm$ 2286) W and the individual subjects values ranged from 3819 W to 10669 W. Maximal PPO was taken from 6, 9, 12 or 15 minutes for each subject depending on when the largest increase from baseline was observed (Table 5). The mean ($\pm$ SD) of the maximal PPO was 6219 ($\pm$ 2504) W and the individual subjects values ranged from 3819 W to 11264 W. A paired t-test was performed between the maximal PPO and the baseline PPO, the increase was 744 W ($p = 0.002$; 95% CI 369 to 1119 W). The
mean (± SD) percentage increase in power output was 14 (± 9) %. Five of the subjects showed a maximal increase in power at 12 minutes. Two subjects showed maximal power at 6 minutes and two subjects showed maximal power at 9 minutes. One subject showed no increase in power from baseline during the timeframe.

**Table 5.** Showing raw data for individual subjects. Table is sorted by ‘Time’ in which the maximal power was achieved

<table>
<thead>
<tr>
<th>Subject</th>
<th>Baseline (W)</th>
<th>Max power (W)</th>
<th>Power change (W)</th>
<th>Percentage increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3819</td>
<td>3819</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>10669</td>
<td>11264</td>
<td>595</td>
<td>6</td>
</tr>
<tr>
<td>F</td>
<td>5083</td>
<td>5877</td>
<td>794</td>
<td>16</td>
</tr>
<tr>
<td>B</td>
<td>4774</td>
<td>5523</td>
<td>749</td>
<td>16</td>
</tr>
<tr>
<td>I</td>
<td>3794</td>
<td>4753</td>
<td>959</td>
<td>25</td>
</tr>
<tr>
<td>D</td>
<td>4602</td>
<td>4766</td>
<td>165</td>
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<td>E</td>
<td>8184</td>
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</tr>
<tr>
<td>G</td>
<td>3230</td>
<td>3593</td>
<td>362</td>
<td>11</td>
</tr>
<tr>
<td>H</td>
<td>5858</td>
<td>7602</td>
<td>1744</td>
<td>30</td>
</tr>
<tr>
<td>J</td>
<td>4741</td>
<td>5464</td>
<td>723</td>
<td>15</td>
</tr>
<tr>
<td><strong>Mean (W)</strong></td>
<td><strong>5475</strong></td>
<td><strong>6219</strong></td>
<td><strong>744</strong></td>
<td><strong>14</strong></td>
</tr>
<tr>
<td>± SD</td>
<td>± 2286</td>
<td>± 2504</td>
<td>± 524</td>
<td>± 9</td>
</tr>
</tbody>
</table>

**4.3 Interpretation of Athletic Performance**

It is important, when testing performance to note the smallest meaningful change. In a team sport, this has been quoted as a fifth of the standard deviation between athletes (Hopkins, 2004). For this study, the mean (± SD) baseline PPO was 5475 ± 2286 W. Therefore, smallest worthwhile increase in PPO expressed as a percentage is 8.4%.
4.4 Adjustment for weight

On adjusting the PPO values for weight, the ANOVA still showed no significance ($f = 1.898 \, p = 0.132$). However the standard deviation for the mean values throughout was reduced. The mean ($\pm$ SD) PPO at baseline was $5,475 \pm 2,286$ W. The standard deviation expressed as a percentage of the baseline was 42%. After adjusting for weight, the mean PPO at baseline was $58.8 \pm 17.5$ W/kg. The standard deviation expressed as a percentage was 30%. The paired t-test was still significant after adjustment for weight was made ($p=0.0013$). The smallest meaningful increase in PPO using the adjusted data would be 6%.

4.5 Correlation

A Pearson correlation was carried out between individual maximal PPO produced and individual percentage change between baseline and maximal PPO. An insignificant positive correlation was found ($r = 0.116$). This changed very little when adjusted data was used ($r = 0.186$).
CHAPTER VI
CONCLUSION
6.0 CONCLUSION

6.1 Summary of results
The results of current study showed that there was no significant improvement in PPO during a CMJ at any time interval after a 10 second isometric squat. We must accept null hypothesis one that there is no difference between mean baseline PPO and any of the time intervals after a preload stimulus. However, upon closer analysis, there is evidence that athletic performance as measured by PPO during a CMJ is enhanced on an individual basis after a preloading 10 second isometric squat. Therefore we can reject null hypothesis two which stated that there was no difference between an individuals baseline PPO and their maximal PPO. Sufficient recovery is required prior to the measure of athletic performance as recovery time is highly individualised depending on training experience and strength levels.

6.2 Practical Applications
The current study shows that to take advantage of the long term effects of PAP in the form of complex training, an isometric squat is ideal. Fatigue is minimised due to lower metabolic demands of an isometric movement (Caruso et al., 2003) and performance is maximised, more so then an equivalent dynamic protocol (Rixon et al., 2007). However, prior to use, preliminary work should be carried out by the coach and athlete to determine optimal recovery on a case by case basis. The present study found it to be between 9 and 15 minutes and previous studies have found it to be between 8 and 12 minutes (Kilduff et al., 2007).

Furthermore, the current study shows that the acute effects of PAP can be utilised for events involving single explosive efforts such as sprints or jumps. The isometric squat can be incorporated into a warm-up prior to the event though again, preliminary work should be done to find the athletes individual recovery time prior to maximal performance.

A professional team sport such as rugby would have the whole team training together thereby unifying training methods, this would likely align the recovery
times to a degree. This has been shown in a similar study, which found that there was a significant increase in PPO at 8 minutes (p = 0.002) and 12 minutes (0.001) after a 3RM squat exercise (Kilduff et al., 2007).

In a team setting therefore, it is perfectly feasible to potentiate whole groups of athletes prior to their events by performing a 10 second isometric squat against a wall or low ceiling or even by pushing against each other after being matched for power and mass. Furthermore, in a rugby setting, potentiation could be performed as a group against a scrummage machine. With enough resistance on the machine, a 10 second isometric horizontal squat could be performed as a group of eight players. In a team environment, players could be grouped according to similar recovery times and potentiated in turn on a predetermined timescale. This would be an easier alternative to individual potentiation. Alternatively, if the recovery times of the whole team could be brought closer together by a universal training programme, team potentiation would be more feasible.

6.3 Further work
Any further studies into the phenomenon should use a multiple recovery time format to allow for individual variation. In addition, individual analysis should be carried to detect changes which may be masked.

In terms of practical usage, the current study has verified that an isometric squat can provide an beneficial effect. The next step is to evaluate a truly practical variation such as a squat against a low ceiling or wall (Rixon et al., 2007) or a vertical squat against an opponent or scrummaging machine. Although the biomechanics of these alternatives are very similar, practical considerations may present difficulties such as finding an appropriate matching of opponents or positioning under a low ceiling to allow for a maximal squat.

Furthermore, the level that the squat is carried out at should be evaluated with the aim of maximising the potentiation while minimising fatigue. The current study carried out the isometric squat in the half squat position. Variations on this include squatting from parallel, squatting from below parallel and squatting from
just short of lockout. Further evaluation of the squat position may allow greater gains in potentiation.

The current study has only really focused on potentiation in practical settings prior to an event or game. Further work could be carried out to look into the potential benefits of potentiating throughout a game. It would have to evaluate whether effects of fatigue due to the preload stimulus would outweigh positive benefits of the potentiation. In addition, the preload stimulus would need to be further simplified as any further potentiation in a game would have to be carried out on the pitch during short breaks in play.

Finally, a point was highlighted during the evaluation of the individual subjects in the current study. One of the subjects did not improve at all during the time intervals given and was identified as the subject with the least training experience. Current literature suggests that this was due to fatigue in untrained muscle groups overwhelming any potentiation produced. Perhaps in this case, the preload stimulus was too intense and a less extreme protocol such as a 5 or 7 second isometric squat could provide potentiation without the same extent of fatigue. Different groups of individuals such as older athletes or less trained athletes who suffer more readily from fatigue may still be able to potentiate using specific protocols designed especially for them. Obviously in this setting, the acute effects would be less important and it would be PAP in a complex training setting that would be more important. Further research would have to be carried out to verify the feasibility of this theory.
REFERENCES


Dear Subject

I am a Level 3 undergraduate student in the School of Sport, PE, & Recreation, at the University of Wales Institute Cardiff. I am doing a dissertation on Postactivation Potentiation and wonder if you would be kind enough to help with my research.

The research aims to discover the effects of an isometric squat on power output as measured by jump performance. You will attend a test session where your jump performance will be measured. After a period of time you will perform an isometric squat followed by a further series of jumps. These will allow us to evaluate the effect the isometric squat has had on your jump performance at different intervals.

The research might prove beneficial since it may provide a practical method of improving power output and therefore potentially performance during a rugby match.

Why me?
The criteria for being selected for this research include being, or having recently been a member of a rugby team. In addition to this, participants must also have a history of consistent weight training and must still be participating regularly in weight training.

These prerequisites mean you have the potential to aid in research regarding the practical application of post activation potentiation and optimal recovery time.

Do I have to do it?
No. You are under no obligation to take part in this study. If you choose not to take part no questions will be asked and no reason will be sought. In addition to this, you may decide to take part and then drop out at any point with no reason given. Feel free to forward any queries or concerns to us. Contact information is provided at the end of this form.

What do I have to do?
Please read this sheet fully and ask any questions prior to signing the consent form. It is essential that you understand the details of the study before to agreeing to participate.

Confidentiality
Your participation and results will be kept confidential as far as is humanely possible. No names or identifying information will be included in the academic paper. Any features cited will be those relevant to the research. Your consent form and any information provided will be kept strictly confidential in accordance with provisions of the Data Protection Act (1998). Only the principal investigator
and supervisors will have access to the information. All documents and electronic files associated with the paper will be kept in password protected folders.

**Risks**
The risks of participation include the risks associated with weight training but these have already been minimized by our selection of subjects with training experience. In addition, the warm up session will allow us to coach your technique in the movements which will reduce the risks further.

If you are willing to participate, then please read the slip below carefully, and sign. If you have any queries, do not hesitate to contact me.

Thank you. I look forward to hearing from you.

Emil Hodzovic  
*Principal Investigator*
I have read and fully understood the request to be a subject of Mr Hodzovic's research. I understand what I have to do. I understand the risks involved, and the measures in place in the event of accident. I understand that participation is entirely voluntary, and that withdrawal is possible at any time. I understand the measures that will be taken to uphold confidentiality as far as possible.

I agree to participate.

Signature  
Date
APPENDIX B

Raw Power Data in Table and Figure Form

Table B. Raw Subject PPO Data including Means ± SD and % increase from baseline to maximal PPO

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Baseline (a)</th>
<th>6min</th>
<th>9min</th>
<th>12min</th>
<th>15min</th>
<th>Maximal PPO (b)</th>
<th>% increase between a and b</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3818.5</td>
<td>3525.2</td>
<td>3629.2</td>
<td>3335.9</td>
<td>3633.8</td>
<td>3818.5</td>
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</tr>
<tr>
<td>B</td>
<td>4773.8</td>
<td>4458.3</td>
<td>4693.5</td>
<td>5523.0</td>
<td>5396.3</td>
<td>5523.0</td>
<td>15.7</td>
</tr>
<tr>
<td>C</td>
<td>10669.4</td>
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<td>11264.2</td>
<td>8631.5</td>
<td>9455.7</td>
<td>11264.2</td>
<td>5.6</td>
</tr>
<tr>
<td>D</td>
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<td>4528.3</td>
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<td>5464.4</td>
<td>15.3</td>
</tr>
<tr>
<td>Mean PPO ± SD (W)</td>
<td>5475.4 ± 2285.8</td>
<td>5197.8 ± 1964.2</td>
<td>5754.5 ± 2600.4</td>
<td>5564.0 ± 2039.5</td>
<td>5731.5 ± 2142.5</td>
<td>5754.5 ± 2379.7</td>
<td>5.1 ± 9.2</td>
</tr>
</tbody>
</table>

Figure B. Individual data in chart form showing trends for increase in PPO even after 15 minutes, particularly H and J.
APPENDIX C
Data Adjusted for Weight

Table C. Raw Subject PPO Data including Means ± SD and % increase from baseline to maximal PPO adjusted for weight.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Baseline (a)</th>
<th>6 minutes</th>
<th>9 minutes</th>
<th>12 minutes</th>
<th>15 minutes</th>
<th>Maximal PPO (b)</th>
<th>% increase between a &amp; b</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>44.9</td>
<td>41.5</td>
<td>42.7</td>
<td>39.2</td>
<td>42.8</td>
<td>64.9</td>
<td>0</td>
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<td>B</td>
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<td>51.8</td>
<td>54.6</td>
<td>64.2</td>
<td>62.7</td>
<td>44.2</td>
<td>16</td>
</tr>
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<td>100.9</td>
<td>77.3</td>
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<td>16</td>
</tr>
<tr>
<td>G</td>
<td>40.8</td>
<td>35.0</td>
<td>38.3</td>
<td>45.4</td>
<td>39.2</td>
<td>45.4</td>
<td>11</td>
</tr>
<tr>
<td>H</td>
<td>63.1</td>
<td>68.6</td>
<td>64.5</td>
<td>66.9</td>
<td>81.9</td>
<td>81.9</td>
<td>30</td>
</tr>
<tr>
<td>I</td>
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<td>46.3</td>
<td>56.6</td>
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</table>

Mean PPO ± SD

| (W/kg) | 58.8 ± 17.5 | 56.0 ± 15.6 | 61.7 ± 20.8 | 60.1 ± 15.8 | 61.7 ± 16.9 | 66.9 ± 13.8 |

Figure C. Mean PPO adjusted for weight over the time intervals. Note the decreased SD compared to unadjusted data.
**APPENDIX D**

Baseline Measurements of the Subjects

<table>
<thead>
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<th>Subject</th>
<th>1RM (kg)</th>
<th>weight (kg)</th>
<th>Age (years)</th>
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