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Velocity Specificity in Early-Phase Sprint Training

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Abstract. Kristensen, G.O., R. van den Tillaar, and G.J.C. Ettema. Velocity specificity in early-phase sprint training. *J. Strength Cond. Res. 20(4):833–837. 2006.*—A comparison of resistance running, normal sprint running, and supramaximal running was performed. Nineteen young, generally well-trained subjects were divided into 3 training groups: resistance, normal, and supramaximal groups. Resistance and supramaximal training was done using a towing device, providing extra resistance or propulsion forces, resulting in running speed differences of about 3.3% (supramaximal) and 8.5% (resistance), compared to normal sprinting. The training period was 6 weeks, with 3 training sessions per week (5 sprint-runs over 22 m). Running times were measured using photocells, and average step length and cadence were recorded by digital video. A small (0.5%) but significant ($p < 0.05$) overall pre-post difference was found in running velocity, but the 3 groups changed differently over the running conditions. All individual subjects improved sprinting velocity most on the trained form, at 1–2% ($p < 0.001$), and thus, the principle of velocity specificity in sprint training was supported. This indicates that to obtain short-distance sprinting improvement in a short period of time, one may prefer normal sprinting over other training forms.

Key Words. strength, biomechanics, running

Introduction

It is generally accepted that sprinting performance can be improved considerably by means of strength training. It seems obvious that in sprint running, muscle strength is an important factor, particularly in the acceleration period of the exercise. In order to establish an effective transfer between strength training and sprint running, there is a need for specificity in the strength exercises that mimics sprinting (3). For example, resistance running is regularly applied in training practice. On the other hand, training forms emphasizing the speed aspect of the exercise, that is, running at high speeds using propelling forces (supramaximal running), are considered to be effective forms of training (11). In this type of training, the athlete is allowed to move faster than is normally possible using a pulling device. For both training forms the line of thought is that one can enhance power by focusing on one power factor, force or velocity, specifically. It has been shown previously that training effects in single joints within the force-velocity domain are velocity specific (7). Considerable research with regard to the force-velocity characteristics has been done on single joint and relatively simple movements (6, 13, 15, 16); much research has also been done with regard to training effects of general strength and speed training for sprint performance (2, 3, 8, 10). Still, relatively little is known about the extent to which the principle of speed specificity applies to whole-body actions (e.g., running), where the training and performance movement forms are identical except for the resistance-velocity parameter.

The departure point of this study was to consider resistance running and supramaximal running as 2 different points in a continuum in the force-velocity domain for sprinting. The main aim of this study was to test the hypothesis that the principle of velocity specificity also applies to sprinting; in this case, the sprint start. Hence, a comparison of training effects of resistance running, normal sprint running, and supramaximal running was conducted. In this study, we limited ourselves to investigating the issue with regard to the early phase of training, targeting neural adaptations, possibly including technique changes, and not changes related to muscle hypertrophy. Furthermore, to enhance the potential of training adaptations, we selected well-trained subjects without any specific sprint training experience.

Methods

Experimental Approach to the Problem

To study the question of whether or not sprint training is velocity specific, we studied 3 sprint training forms of different velocity in 3 performance-matched training groups, each of which trained for one of these sprinting forms. We only considered the early phase of training (i.e., 6 weeks), so that our findings may have direct implications for during-season training. To provide an answer for general application in sports, we targeted well-trained subjects who did not have a particular sprint training background. We compared the pre- and posttraining changes for these 3 groups with regard to all 3 sprinting forms. If the groups would show best improvement in the sprinting form they trained for, the velocity specificity hypothesis would be confirmed for sprint training in nonsprinters.

Subjects

Nineteen young, healthy, and generally well-trained subjects (first-year sport science students; 12 male, 7 female) who were all active in competitive sports participated in the study (age, 22.0 ± 2.6 years; height, 1.76 ± 0.08 m; weight, 73.8 ± 8.8 kg at the pretest and 73.6 ± 8.5 kg at posttest). None of the subjects had previous experience with specific sprint training. The experiments were performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Ethical clearance was obtained from the local ethics committee. All subjects were fully informed about procedures, and informed consent was obtained prior to the first tests. The subjects were divided into 3 training groups: resistance, normal, and supramaximal groups. The groups were matched for 20-m sprinting performance prior to the main experiments. The females were equally divided into

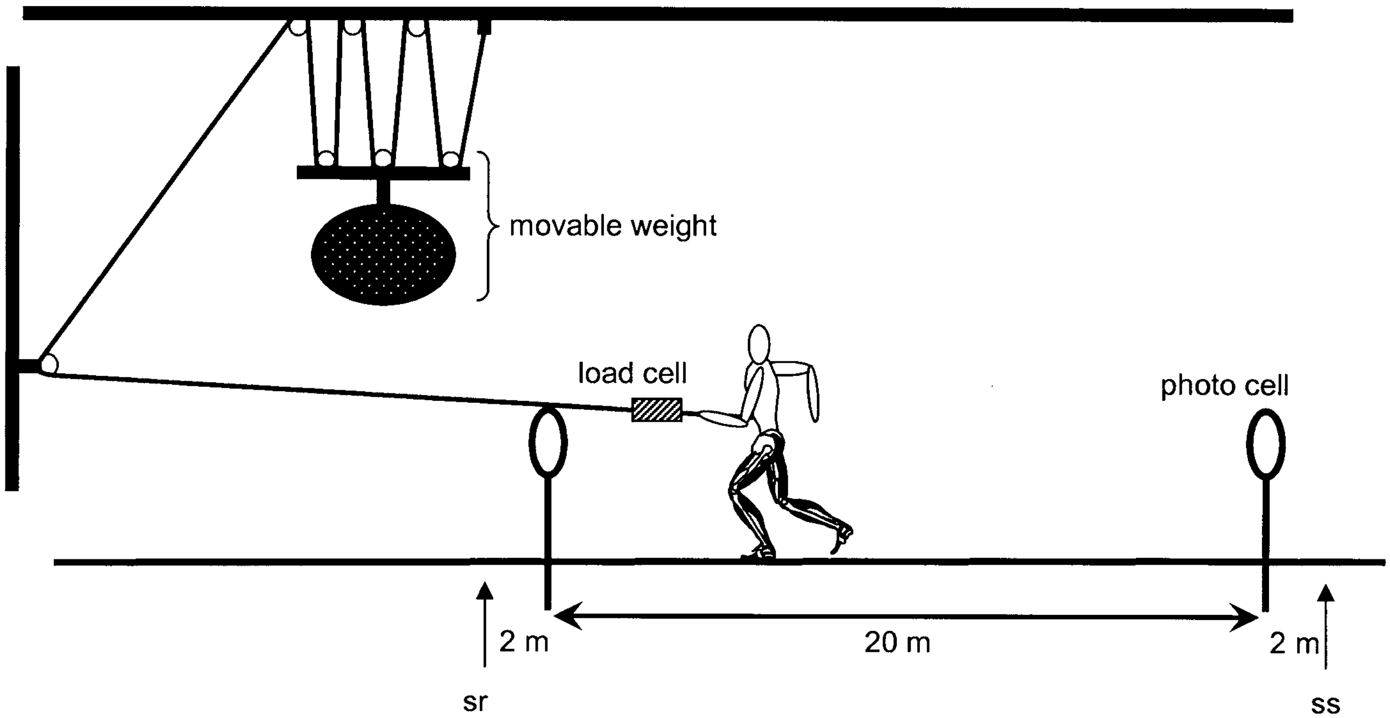

FIGURE 1. Experimental set-up, showing towing system and subject running in supramaximal speed condition (ss). For resistance running, the running direction was altered (sr). Running performance was measured between the 2 photocells (20 m). The load cell was only mounted in the pilot studies and calibration runs.

the 3 groups. As the aim of this study was to compare different training forms with each other, and not to test the absolute effect of training, we did not include a nontraining control group.

Training Protocol

Resistance and supramaximal training was done using a towing device (Figure 1), which provided extra resistance or propulsion force, depending on the running direction with regard to the system. Seven castors (3 fixed to the ceiling, 1 at the wall at a height of 1.5 m, and 3 on a movable fixation bar) were used for the towing system, creating a 1:6 gearing ratio between weight and subject. A 5-mm rope was fastened in the roof 7 m above the floor. The rope was led through the castors and fastened to the subjects in the middle of the upper body by means of a climbing vest. The appropriate weight was attached to the movable fixation bar. We aimed at obtaining relatively small-velocity differences between the running conditions to be assured of comparable running techniques (9). In a pilot study (n = 6; same set-up as main experiment, but using several weights, 3 times each), resistance and propulsive forces values were ascertained to give a running speed difference of approximately 6% compared to that associated with normal sprinting. In this pilot study, resistance and propulsive forces were recorded by a load cell mounted on the rope close to the subject. The total movable weights attached to the system were 15 kg (resistance) and 35 kg (supramaximal), leading to additional forces, while standing still, of approximately 27 N and 75 N, respectively. The load cell was not used during training sessions and during actual pre- and posttests, as the weight of the cell was somewhat disturbing.

All groups trained for 6 weeks, with 3 training sessions per week. One training session consisted of a standard warm-up and 5 sprint-runs over 22 m under the specific conditions, depending on the training group. During training, all subjects were verbally encouraged. No feedback was given on performance.

Test Protocol

Pre- and posttests were performed in the week just before commencement of training and the week following the last training week, respectively. All subjects performed a traditional warm-up session (jogging) before the tests. All subjects were instructed to run with maximal effort in all trials, but they received no feedback on their performance. For practical reasons, the order of test conditions was set at normal condition (3 times), resistance condition (3 times), and supramaximal condition (3 times). A 4-minute rest period was used before each trial. Because of the same fixed order for both pretest and posttest and because of the rest periods between trials, a possible effect of nonrandomized testing on the results was deemed minimal.

In all sprint tests, running times were measured using photocells. Subjects started their performance 2 m before the first measurement point, so that the very initial acceleration was not taken into consideration. Furthermore, average step length (distance between initial foot-ground contact to the next one) and cadence (steps·s^{-1}) were recorded for the 20-m distance (50-Hz digital video, analyzed with National Institutes of Health software, Bethesda, MD).

Statistical Analyses

For a general description and localizing training effects, a 2-way analysis of variance (ANOVA; training group vs.

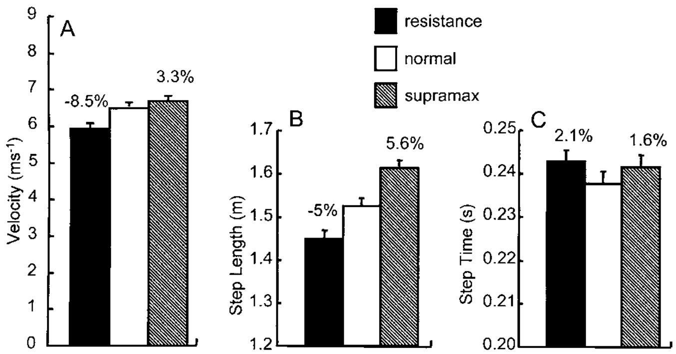

FIGURE 2. (A) Pretraining running performance for all subjects expressed as mean velocity over 20 m (mean and *SEM*; $n = 19$). Differences with normal running are also indicated as percentage of normal running. Both resistance and supramaximal speed velocities are significantly different from normal velocity. (B, C) Mean step length and step time over the entire distance, respectively. Differences with normal running are significant.

test condition) for repeated measures was used. To test the specific hypothesis that one would improve most on the condition that one trained for, a binomial test (probability 0.33) was used on all 19 subjects. For all tests, the probability level for significance was set at $p \leq 0.05$. The intraclass correlation coefficient (ICCR) on test-retest comparisons (3 repeats per condition) amounted to 0.905. Applying the same statistics on the mean performance in the 6 conditions (3 test conditions combined with pre- and posttest), an ICCR of 0.990 was found, indicating a highly intraindividual consistency from condition to condition. The statistical power was 0.45 for training effects and 1.0 for group differences.

RESULTS

All subjects underwent a pre- and posttest on all 3 sprinting conditions. The pretest running speeds (average over the entire 20 m) were 6.67 (±0.40), 6.45 (±0.41), and 5.88 (±0.45) $m \cdot s^{-1}$ for supramaximal, normal, and resistance running, respectively (Figure 2A). The 3.3% (supramaximal) and 8.5% (resistance) difference with normal speed were statistically significant ($p < 0.05$; ANOVA, repeated measures). The differences in velocity are accounted for mainly by significant differences ($p < 0.05$) in step length (Figure 2B). Step time (Figure 2C) is elevated somewhat in both supramaximal and resistance running compared to normal running ($p < 0.05$).

Training Effects

The pre-post differences are shown in Figure 3. Overall, only a small (0.5%) but significant ($p < 0.05$) overall pre-post difference was found in running velocity. The average improvement is quite small, which is partly due to a negative effect for 2 conditions (resistance group in normal [$p = 0.05$] and supramaximal speed running). The only group-condition combinations showing a significant improvement were the normal group in normal running and the supramaximal group in normal and supramaximal running. A 2-way ANOVA, repeated measures, indicated no significant main effects by training group or test form on pre-post differences, with low observed statistical power for group effect, 0.252, and test form, 0.252, indicating that small overall differences between groups and

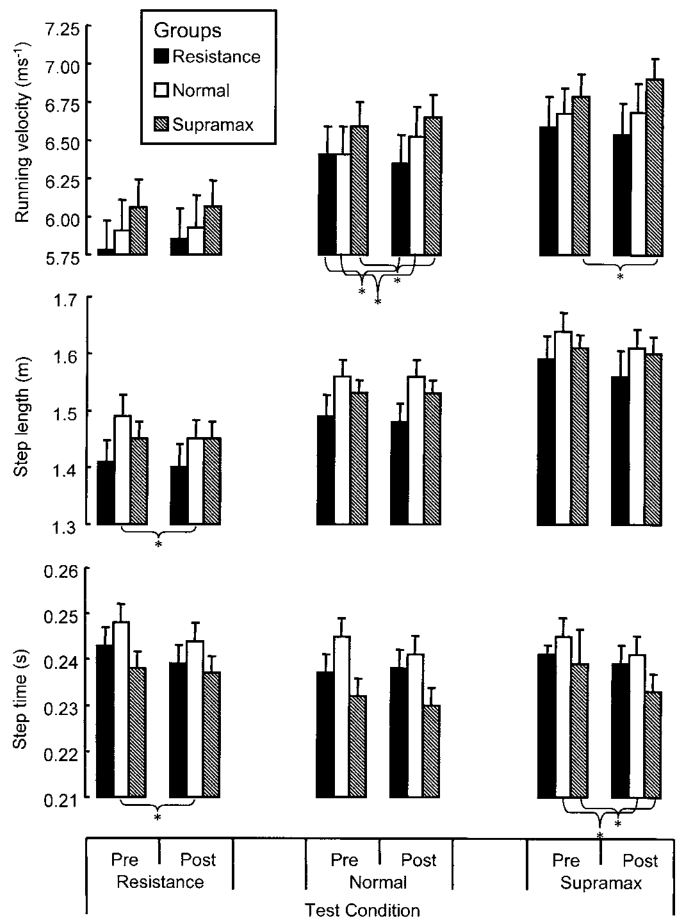

FIGURE 3. Pre- and posttest training comparison for all groups and running conditions. For analysis of variance statistics, see text. * Local significant pre-post differences.

test forms may exist. Within each test form, training form affects performance differently (significant group-condition interaction, $p < 0.001$). For example, the difference in training effect for normal running between the resistance group (negative effect) and the other 2 groups (positive effect) was significant. Figure 4 shows a 3 × 3 matrix on change of performance between post- and pretest and demonstrates that the best improvements were established in the activity that was also trained (striped diagonal). To test the specific hypothesis that one would improve most on the condition that one trained for, a binomial test (probability 0.33) was used on all 19 subjects. All individual subjects improved most on the trained form, leading to high statistical significance ($p < 0.001$).

A less clear situation exists for step length and step time changes. Overall, both step length and time reduced after training ($p < 0.05$ and $p < 0.01$, respectively) by, on average, 1%. The ANOVA revealed no particular dependencies on group, running condition, or interaction.

DISCUSSION

The aim of the present study was to establish if there exists any training specificity with regard to speed of movement in sprinting. Using a 3 × 3 matrix of training groups and sprint test conditions, we found that each group improved most at their own training condition. Thus, the current results are indicative for speed speci-

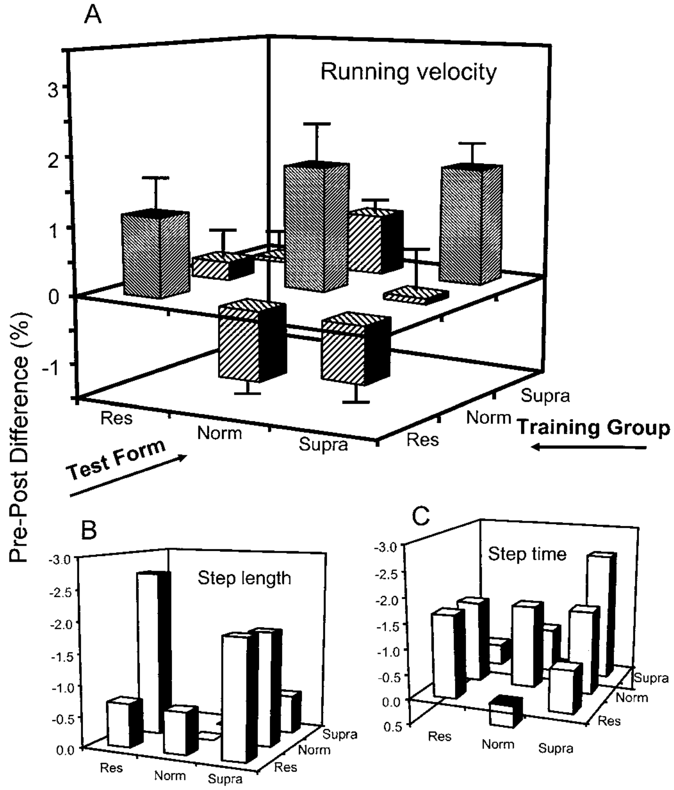

FIGURE 4. Changes in running performance in a 3 × 3 matrix, shown as pre-post differences in percentage of pre-test values. (A) Running velocity; the thin-dashed bars at the diagonal indicate that the best improvement was obtained at the same test as training condition (binomial test, probability 0.33; $n = 19$; $p < 0.001$); (B) step length; (C) step time.

ficity (6) in sprint running with regard to training. In more detail, the only (weak) transfer to speeds other than the trained speed seems to be toward the slower speeds, which is in favor of supramaximal speed training forms. A negative effect on normal sprint performance was found in the resistance-training group. McBride et al. (10) came to similar findings with regard to the training associated with heavy resistance squats. Also, Delecluse et al. (1) came to qualitatively similar conclusions (i.e., that high-velocity strength training overall gave better improvements than high-resistance training). We emphasize that given the short duration of training (6 weeks) in the current study, the adaptations that caused performance improvement are to be considered as the early-phase changes and are most likely of a neural nature. These neural adaptations may include a change in intermuscular coordination and running technique; the latter we only recorded roughly by stride length and cadence.

The current study did not contain a nontraining group to which the training groups could be compared. Thus, statistically, we cannot conclude that the pre-post differences were caused by the training protocols. However, the interest in this study was to assess differences between training protocols rather than to establish if specific sprint training improves sprinting performance. Still, given the well-documented nature of specific training, the specific results, and the degree of improvement found in this study (see below), we are inclined to conclude that the major cause for the pre-post differences was training rather than other time-dependent events. Although this study was not designed to examine effects of gender, the present data give no indication to conclude that a gender influence exists in early-phase sprint training.

The overall training effects seem small but were extremely consistent. The specific improvement is in the same range as was found for kayak sprinting (8). Furthermore, the small increase in velocity is somewhat misleading with respect to performance improvement. With a simple model, we calculated the power required for increasing velocity from zero to any particular level over a particular distance with an acceleration that decreases linearly in time to zero (i.e., one obtains a maximal velocity). We took 10 m for this acceleration phase (1). Whereas the total power required to obtain a particular speed depends on this change of acceleration in time (e.g., one can also assume a constant acceleration), the power increase required for a particular sprint velocity improvement was independent of the model choice was about threefold that of the velocity improvement (8). In other words, the 1–2% improvement in the specific test conditions found in this study is likely brought about by about 3–6% power enhancement.

Step length, not cadence, seemed to be the steering parameter between the running conditions, with a 5.6% and 5.0% difference between normal running and resistance and supramaximal running, respectively. This is in agreement with the results of Mero et al. (12) and Lockie et al. (9). Intuitively, one might hypothesize that step length would also be the major component driving training effects. Our results do not support such a hypothesis. Although not significant, both step length and step time decreased after training. The only visible trend in the 3 × 3 matrix (Figure 4) is that the diagonal (equal training and test form) shows a clear reduction in step time. In other words, if anything can be indicated from the current results, it is that step time is reduced after training (14, 17). These observations are in agreement with the observed improvement of sprint performance with creatine supplements and associated increase in step frequency (18). Otherwise, the ability to activate muscle fully at high contraction velocities may have been enhanced (4). Regardless, these findings indicate that contraction kinetics rather than maximum isometric strength is an important muscular performance factor in sprinting. Of course, we cannot say whether changes in our subjects at the level of contraction kinetics have occurred. But since our results trend in the same direction identified by Schedel et al. (18) with regard to targeting contraction kinetics, we are inclined to suggest that our training protocols targeted neural adaptations enhancing the speed aspects of contraction rather than pure strength. Clearly, more detailed studies are necessary to elucidate this further.

To avoid clear alterations in running technique between running conditions, we chose to limit the difference in resistance and running speed (9), an approach used in praxis as well. This approach, however, limits the possibility to study effects within a wider spectrum of resistance-velocity combinations. The question then remains of whether, when applying a wider range, one is able to compare similar whole-body movements.

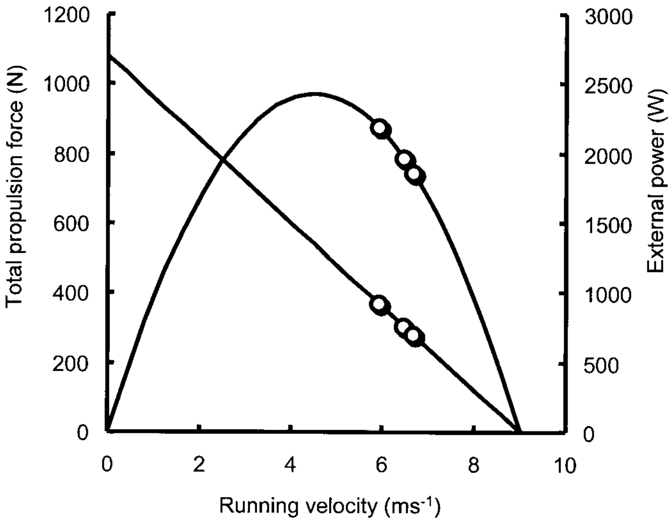

FIGURE 5. Comparison of the training conditions and a hypothetical force-velocity relationship for sprint running. The 3 markers indicate, from left to right, resistance, normal, and supramaximal sprinting. The velocities of these 3 data points are mean values from this study; the forces and power are taken from the hypothetical curves.

To obtain some global indication for the actual range in the resistance-velocity that was targeted in this study, we used some data available from the literature: maximal isometric force in extension of the lower limb was set at 110 kg or 1,080 N for 1 limb (2) and maximal fully unloaded sprint velocity at 9 $m \cdot s^{-1}$ for the group of subjects in our study. Furthermore, for sprinting, a linear relationship between resistance and running speed was assumed (5, 9, 19). It appeared that the range of velocities obtained in the present study occurs at the area of moderate to high velocities (Figure 5) and at very-high to high power production, but these indications are rather sensitive for the estimate of maximum velocity (a maximum velocity of 12 resulted, in that all 3 training forms occur near peak power). Independent of this, it appeared that the velocity range from resistance to supramaximal training is rather narrow compared to the entire velocity spectrum.

PRACTICAL APPLICATIONS

Our results indicate that to obtain short-distance sprinting improvement in a short period of time, one may prefer normal and supramaximal sprinting over resistance sprinting. Our findings might be applicable more or less directly to athletes engaged in sports in which short-distance sprinting is important but not the only key factor for performance (e.g., basketball, soccer) and for which sprint training opportunities are limited. However, one should be extremely careful when generalizing these findings to other groups, training status, and duration of training, as it is possible that the adaptations to training that have occurred are of a different nature than adaptations that occur over a longer period of experience with sprint training.

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