Effects of an 8-Week Aerobic Exercise Training on Saliva Steroid Hormones, Physical Capacity, and Quality of Life in Diabetic Obese Men

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Key words
- physical activity
- cortisol
- DHEA
- testosterone
- 6-minute walking test

Abstract

The purpose of the study was to assess the effects of aerobic exercise training on saliva steroid hormones [i.e., cortisol, dehydroepiandrosterone (DHEA), and testosterone], physical capacity, and quality of life in obese diabetic men. 8 abdominally obese type 2 diabetic men (59.5 ± 1.7 years old, BMI = 35.5 ± 1.6 kg/m^2, waist circumference = 119.4 ± 3.3 cm) and 9 healthy men (57.4 ± 1.5 years old, BMI = 24.5 ± 0.8 kg/m^2, waist circumference = 92.3 ± 1.9 cm) participated in the study. The obese diabetic men underwent 8 weeks of aerobic exercise training: twice a week 45 min sessions at 75 % of peak heart rate and once a week 45 min session of intermittent exercise. Before and after training, steroid hormone concentrations were analyzed from saliva samples, physical capacity was assessed by the 6-minute walking test, and quality of life was estimated by a specific questionnaire for obese subjects. These data were compared with the data from the healthy untrained men. The basal saliva DHEA and testosterone concentrations, physical capacity, and quality of life scores of the obese diabetic men were significantly lower than those of the healthy men. Aerobic training induces a significant increase in the 6-min walking distance and improve the psychosocial impact dimension of quality of life, without modifying significantly any other parameter investigated. These data suggest that an 8-week aerobic exercise program improves physical capacity and quality of life in obese diabetic men, but was insufficient to correct the anthropometric and hormonal alterations observed in this population.

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Introduction

The prevalence of obesity and type 2 diabetes continues to rise in the world. It appears from the literature that obese diabetic individuals, in particular those with abdominal obesity, present a deterioration in endocrine function, which may amplify disease morbidity [1–3]. Disturbances in the hypothalamo-pituitary-adrenal (HPA) axis have been found in abdominally obese diabetic patients, and alterations in cortisol metabolism may play a pathogenic role in metabolic disturbances [1,2]. Abdominally obese diabetic men also suffer from other steroid hormone alterations, including diminished dehydroepiandrosterone (DHEA) and testosterone [3–5]. Regular physical activity is one of the therapeutic recommendations for this population, as many studies have concluded that exercise with or without weight loss can improve several of the metabolic disturbances found in these obese patients [6–12]. However, to our knowledge, the effects of exercise training on steroid hormone alterations have never been specifically studied in the abdominally obese diabetic population. Indeed, some studies have investigated the effects of exercise training on cortisol concentration in the general obese, overweight, and diabetic populations, but without specifying the fat mass distribution (peripheral or abdominal) [13–16]. Similarly, only 3 studies of type 2 diabetic men, 2 without systematic obesity [5,15] and 1 in overweight men [14] have been performed and concluded that exercise training may increase DHEA without modifying testosterone concentrations [15]. Quality of life (QoL) also appears to be disturbed in the obese diabetic population [17,18]. It is consequently an important subjective parameter that should be included in weight management evaluation. Although the benefits of aerobic training have been well documented for individuals with obesity or diabetes, further study is needed in populations with a high number of metabolic risk factors. To our knowledge, only 2 studies have investigated QoL in men from this type of population after Tai Chi and Qigong [19] programs or resistance exercise training [20]. However, no study has yet determined the effects of aerobic exercise training on QoL in this population. We therefore assessed the effects of 8 weeks of aerobic training on physical capacity with the validated 6-minute walking test (6MWT) and on steroid hormones with saliva samples, which correctly reflect blood concentration in both healthy and obese diabetic men. In parallel, the effects of training on QoL were evaluated with a specific questionnaire for the obese.

Materials and Methods

Subjects

8 abdominally obese type 2 diabetic men (59.5 ± 1.7 years old, BMI = 35.5 ± 1.6 kg/m^2, waist circumference = 119.4 ± 3.3 cm) and 9 healthy men from the same age group (57.4 ± 1.5 years old, BMI = 24.5 ± 0.8 kg/m^2, waist circumference = 92.3 ± 1.9 cm) participated in the study. All obese diabetic men were treated with oral antidiabetic agents and slow insulin (mean duration of diabetes: 18.7 ± 6.9 years) and all were taking hypertension and dyslipidemia medication, with no modification in treatment during the study. Before inclusion in the exercise program, the obese diabetic men underwent a medical examination and a symptom-limited cardiopulmonary treadmill exercise test in order to verify their cardiac health and determine their maximal heart rate. Criteria inclusions were: having normal physical examinations, no limitation for physical activities, stable weight (< 3 % variation over the month before the study), no participation in regular moderate or intensive exercise for at least 3 months before the study, and not following a diet. None of the obese diabetic or healthy men had to use medication known to affect body mass or steroid secretion. Each subject provided written informed consent to participate in the study, which was carried out in accordance with the Declaration of Helsinki and the local ethical standards.

Anthropometric measurements

Height, body mass, and waist circumference were measured to the nearest 0.1 kg or 0.1 cm, with men wearing only underwear. Waist circumference was taken between the iliac crest and the lateral costal margin at the end of expiration, while the investigator was facing the subject. Body mass index (BMI) was calculated as weight (kg) divided by squared height (m^2).

Usual diet evaluation

Before the start of the study, subjects were instructed on completing a 3-day food diary (including 1 weekend day). These data were analyzed with Bilnut® software to obtain total energy intake. Subjects were asked to maintain their usual diet during the study.

Physical activity level evaluation

Physical activity level was evaluated with the International Physical Activity Questionnaire-Short Form (IPAQ-SF) [21], which has already been used in the obese population [22]. The questionnaire took approximately 15 min to complete, and the investigator was present to assist the subjects. Following the IPAQ guidelines (www.ipaq.ke.se), physical activity data obtained with the IPAQ-SF were computed for metabolic equivalent (MET-min/week) and used to determine 3 categories: low, moderate and high levels of physical activity. The following METs values are proposed by the IPAQ guidelines: Walking = 3.3 METs, Moderate PA = 4.0 METs, and Vigorous PA = 8.0 METs. Using these values, we defined 4 continuous scores according to IPAQ guidelines: Walking MET-min/week = 3.3 × walking minutes × walking days × 7 days; Moderate MET-min/week = 4.0 × moderate-intensity activity minutes × moderate days × 7 days; Vigorous MET-min/week = 8.0 × vigorous-intensity activity minutes × vigorous-intensity days × 7 days; Total physical activity MET-min/week = sum of Walking + Moderate + Vigorous MET-min/week scores. Moreover in the IPAQ-SF, a question about time spent sitting gave an additional indicator of sedentary activity but was not included as part of any summary score of physical activity.

Physical capacity measurement

The 6MWT, which has been validated in healthy [23] and obese [24,25] populations, evaluated physical capacity. As advised in the ATS statement [26], the test was administered on an indoor 30 m course and subjects were instructed to walk as far as they could in 6 min. To allow for potential learning effects, subjects unfamiliar with the 6MWT completed 2 tests, each separated by 30 min of rest. With a slight modification in the ATS guidelines, subjects were informed of the time elapsed and were given standard encouragement: "you are doing a good job" at 3 and 5 min and not every 30 s. After 6 min, the distance covered was measured to the nearest meter. Electronic pulse monitors (Polar® S710) were used to record heart rate at standing rest and throughout the test. Mean heart rate during the 6MWT was calculated from the heart rate recorded during the last 3 min. Heart cost was the 6MWT distance divided by 6MWT heart rate. The 6MWT was performed at the same time of day before and after exercise training.

Quality of life evaluation

QoL was evaluated using the Quality of Life, Obesity and Dietetics questionnaire (QOLOD), which is an obesity-specific questionnaire, validated in French by Ziegler et al. [27]. This self-report consisted of 36 items grouped into 5 dimensions. QoL scores for each dimension were calculated by adding together responses and were then transformed into percentages. Hence, the higher the score, the better the QoL.

Saliva collection and analysis

Saliva (1 ml) was collected using Salitubes (DRG Diagnostics®, Germany). The Salitubes were promptly stored within a hour at −20 °C until analysis. Each sample had to be frozen, thawed, and centrifuged at least once to separate the mucins. Saliva cortisol, DHEA, and testosterone concentrations were measured by ELISA (kits from DRG Diagnostics®, Germany). The detection limits of the assays were 0.0012 for saliva cortisol ng·ml^{-1}, 2.2 pg·ml^{-1} for saliva DHEA, and 1.9 pg·ml^{-1} for saliva testosterone, respectively. Assays were made in duplicate and coefficients of variation for all parameters were always < 10 %.

Exercise training sessions

The 8-week training program, performed only by the obese group, consisted of supervised aerobic activity (walking and ergocycling) 3 days/week at 2 intensities. Water was given ad libitum during each training session. Exercise intensity was individually based on maximal heart rate, previously determined during the symptom-limited cardiopulmonary treadmill test. Twice a week, continuous exercise sessions were conducted at

75 % of peak heart rate for 45 min. Once a week, intermittent exercise sessions were conducted, consisting of 10 min of warm-up and recovery at 65 % of peak heart rate and five 2-min exercise bouts at 85 % of peak heart rate separated by 3-min exercise bouts at 60 % of peak heart rate; these sessions also lasted 45 min. Subjects participated in group or individual sessions, depending on their availabilities. Electronic pulse monitors (Polar® S710) were used to control exercise intensities.

Experimental design

After enrollment, the obese diabetic men and healthy men were asked to come to the hospital for evaluation in the week before the start of the experiment. The obese diabetic men came one more time, in the week after the aerobic exercise program. During these visits, a saliva sample was first collected at 8:30 AM, 2 h after awakening, and an overnight fast. Second, anthropometric variables were measured. The subjects then filled out the IPAQ-SF and the QOLOD questionnaire. Last, 45 min after ingesting a standardized lunch, they performed the 6MWT at 1:30 PM. Food intakes were evaluated 3 days before the hospital visit in both the healthy and obese diabetic groups. Moreover, in the obese diabetic group, food intakes were recorded every 15 days until the end of training and the 2 hospital saliva samples were completed with 3 home saliva samples (every 15 days) collected in the same conditions.

Statistical analysis

The results are presented as mean values ± standard error of the mean (SEM). The normality of the samples was evaluated with histogram distribution, which evidenced a lack of normality for all parameters. The comparison of the 2 groups (obese diabetic men vs. healthy men) therefore was made with Mann-Whitney test. The effects of training were tested with signed rank Wilcoxon tests, except for diet and hormonal parameters, which were analyzed for time variations using a Friedman test in the obese diabetic group. Data were analyzed with Statview® 5.0 software. The null hypothesis was rejected at $p < 0.05$.

Results

Anthropometric measurements (▸ Table 1)

Significantly higher weight, BMI, and waist circumference were observed before and after training in the obese diabetic men compared with the healthy men ($p < 0.001$). No significant change in weight, BMI or waist circumference was observed after training in the diabetic group.

Diet evaluation (▸ Table 2)

No significant difference in diet was observed between groups or between intakes of the 5 dietary foods that were used to evaluate kilocalorie intake during the training period of the obese diabetic men.

Level of physical activity (▸ Table 1)

Energy expenditure (total, intense, moderate, and walking) and time sitting did not significantly differ between groups, except for walking after training in obese diabetic, which is significantly higher compared to healthy subjects. Exercise training significantly increased the level of total energy expenditure ($p < 0.01$) and the level of energy expenditure with intense physical activities ($p < 0.05$) and walking ($p < 0.05$). Therefore, all obese diabetic men showed a change in physical activity level (low to moderate or moderate to high level) after exercise training. In contrast, time sitting and energy expenditure with moderate physical activity did not significantly change after the training period in these subjects.

Physical capacity (▸ Fig. 1)

Walking distance and heart cost in the obese diabetic men before and after training were significantly lower than in the healthy men ($p < 0.001$). The percentage of walking distance for the obese diabetic men compared with the healthy men increased significantly, from 71.8 % (± 3.9) before training to 75.3 % (± 3.9) after training. No difference in resting or 6MWT heart rate was noted between groups. There was a significant increase in

Table 1 Body mass, body mass index (BMI), waist circumference, physical activity (PA), and sitting time (mean ± SEM) in 8 diabetic obese men before and after 8 weeks of aerobic exercise training (Tr) compared with the baseline values of 9 healthy men

	Healthy men	Obese diabetic men	
		Before Tr	After Tr
Body mass (kg)	79.6 (± 2.7)	105.9 (± 4.7)$	105.9 (± 4.6)$
BMI (kg/m²)	24.5 (± 0.8)	35.5 (± 1.6)$	35.5 (± 1.5)$
Waist circumference (cm)	92.3 (± 1.9)	119.4 (± 3.3)$	118.2 (± 2.9)$
Total PA (MET-min/week)	1 893.0 (± 298.6)	1 024.7 (± 270.8)	3 332.9 (± 745.4)*
Intense PA (MET-min/week)	165.1 (± 95.3)	30.0 (± 30.0)	572.0 (± 271.3)*
Moderate PA (MET-min/week)	1 066.2 (± 292.6)	392.5 (± 141.8)	867.5 (± 246.8)*
Walking (MET-min/week)	662.2 (± 290.2)	602.2 (± 158.9)	1 893.4 (± 543.3)*$
Sitting time (min/day)	400.0 (± 50.9)	405.0 (± 33.5)	360.0 (± 45.3)

*$p < 0.05$, significantly different after training compared with basal values; $$p < 0.05$, significantly different from that of healthy men

Table 2 Energy intake, salivary (S) cortisol, salivary dehydroepiandrosterone (DHEA), and salivary testosterone (mean ± SEM) in 8 diabetic obese men, evaluated every 15 days (D0, D15, D30, D45, D60) during 8 weeks of aerobic exercise training (Tr), compared with the baseline values of 9 healthy men

	Healthy men	Obese diabetic men				
	D0	D0	D15	D30	D45	D60
Energy intake (kcal/day)	1 892.0 (± 100.4)	1 936.0 (± 85.6)	2 050.4 (± 68.4)	2 034.6 (± 107.3)	2 003.0 (± 107.4)	2 012.0 (± 88.7)
S Cortisol (ng·ml⁻¹)	5.5 (± 1.3)	6.5 (± 1.4)	4.9 (± 1.6)	6.5 (± 2.1)	5.8 (± 1.2)	3.8 (± 0.7)
S DHEA (pg·ml⁻¹)	134.7 (± 16.6)	31.8 (± 8.4)$	30.5 (± 8.0)$	34.7 (± 10.4)$	39.9 (± 10.3)$	43.7 (± 12.0)$
S Testosterone (pg·ml⁻¹)	58.0 (± 10.1)	25.7 (± 5.7)$	21.9 (± 4.6)$	26.6 (± 5.3)$	23.7 (± 5.6)$	20.7 (± 3.6)$

$$p < 0.05$, significantly different from that of healthy men

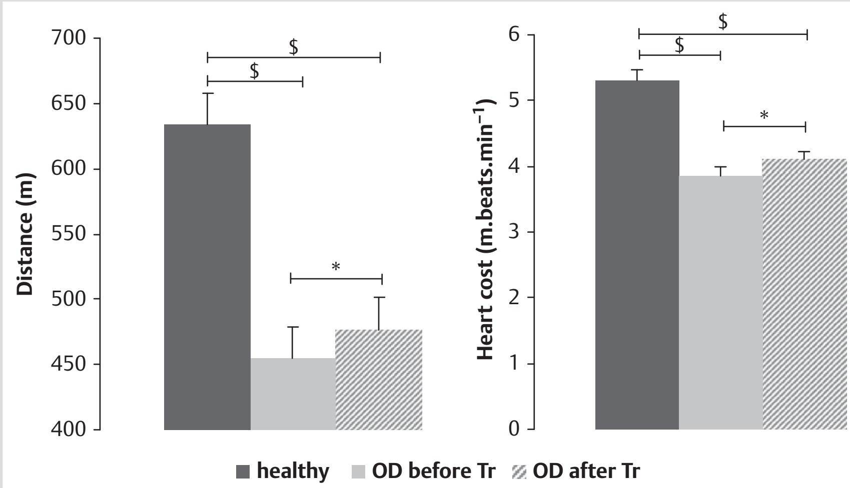

Fig. 1 Distance ambulated and heart cost (mean ± SEM) during the 6-minute walking test in 8 obese diabetic (OD) men before and after 8 weeks of aerobic exercise training (Tr), compared with the baseline values of 9 healthy men. $^*p<0.05$, significantly different after training compared with basal values. $^{\$}p<0.001$, significantly different from that of healthy men.

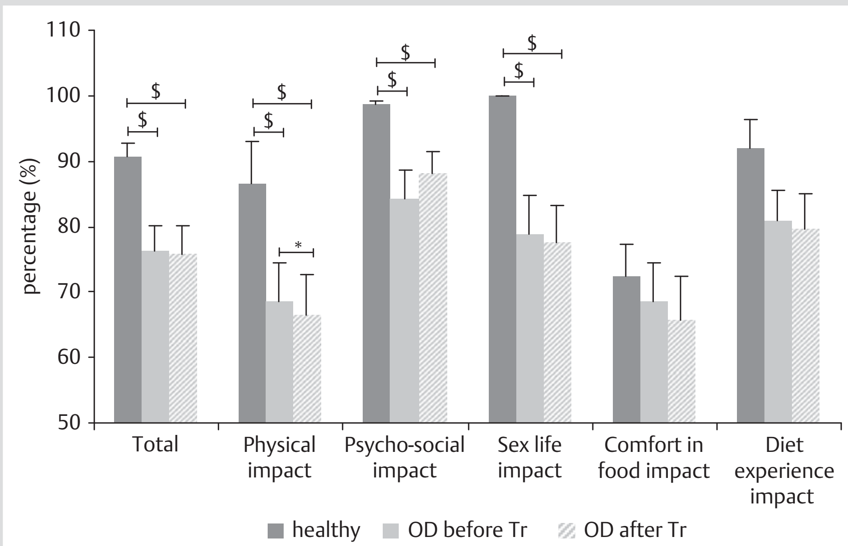

Fig. 2 Quality of life items (mean ± SEM) in 8 obese diabetic (OD) men before and after 8 weeks of aerobic exercise training (Tr), compared with the baseline values of 9 healthy men. $^*p<0.05$, significantly different after training compared with basal values. $^{\$}p<0.05$, significantly different from that of healthy men.

walking distance (22 ± 7.2 m, + 4.8 %, p = 0.028) and heart cost (+ 7.8 %, p = 0.025) in the 6MWT with physical training in the obese diabetic men, but no significant variation in resting or 6MWT heart rate was noted after aerobic exercise training.

QoL (◉ Fig. 2)

The obese diabetic men had a significantly lower total QoL and they scored significantly lower on the physical, psychosocial, and sex life impact dimensions before and after training compared with the healthy men ($p<0.05$). No significant difference between the 2 groups was found for the comfort in food impact or diet experience impact dimensions.

We noted a significant increase in the psychosocial impact dimension in the obese subjects after training ($p<0.05$). However, no significant change in total QoL or the other dimensions was observed.

Salivary hormone concentrations (◉ Table 2)

Compared with the healthy men, the obese diabetic men had significantly lower DHEA and testosterone saliva concentrations at baseline ($p<0.05$) but they showed no significant difference in saliva cortisol concentrations. The ANOVA revealed no significant time effect of training on cortisol, DHEA, or testosterone saliva concentrations in the obese subjects.

Discussion

This study shows that 8 weeks of aerobic training increases physical capacity and improves the psychosocial impact dimension of QoL in abdominally obese diabetic men, but the program was unable to correct the alterations in anthropometric measures, total QoL, or saliva steroid concentrations.

No modification in energy intake or weight was observed in these obese diabetic subjects after the 8 weeks of training despite a significant increase in the total energy expenditure. This situation is in accordance with the literature, which indicates that physical activity alone often stabilizes weight rather than generating weight loss [28]. We also found no significant difference in waist circumference after the intervention, although some studies have shown reduced waist circumference without weight loss [10, 29, 30]. We assume that our intervention was too short to observe this modification, as the other studies lasted at least 13 weeks.

The obese diabetic men showed significantly lower 6MWT distance and heart cost compared with the healthy men and the percentage of normal walking distance was only 71.8 % (± 3.9) of that of the healthy men before training and 75.3 % (± 3.9) after training. These results confirm that submaximal exercise capacity is decreased in the obese diabetic, in agreement with previous studies [31, 32]. Moderate but significant increases in the distance ambulated in the 6MWT, the percentage of normal walking distance, and heart cost were found ($p < 0.03$) after aerobic training without significant changes in heart rate. As this validated test reflects physical capacity in obese subjects [24], we conclude that our training program was efficient in increasing the physical capacity of our subjects. However, this result should be interpreted with caution because no research has actually defined the threshold of clinically significant distance improvement in the obese population after exercise training. In patients with COPD, Redelmeier et al. [33] suggest an improvement of more than 70 m in 6MWT distance after an intervention for a clinical significance. The lesser improvement (22 ± 7.2 m) found in our results may be explained by the functional limitation of our population (toe amputation, joint pain, or hip prosthesis). Consequently, we used also heart cost that reflects exercise intensity to observe the effect of training on physical capacity. To our knowledge, no study has used heart cost with the 6MWT and thus we could not compare our findings with the literature. But, trials that employ heart rate or heart cost to monitor exercise intensity should use these indications with vigilance when exercise is longer than 10 min. Indeed, classic cardiovascular drift is characterized by findings of decreasing stroke volume and mean arterial pressure and stable cardiac output, with rising heart rate after about 10 min of sustained constant-load exercise [34, 35]. However, recent studies [34, 35] indicate that, when dehydration is prevented by fluid intake, cardiovascular drift pattern is altered [35] without significant reduction in exercise intensity during 30–90-min exercise sessions [34]. Moreover, as the post-training walking performances remained significantly lower in the obese diabetic men than in the healthy men, it appears that an 8-week aerobic exercise program can only partially correct their altered physical capacity.

We observed a significantly lower total QoL in the obese diabetic men than in the healthy men. This alteration has already been reported in both obese [18] and diabetic [17] populations. Nevertheless, our results show no significant alteration in the comfort in food impact or diet experience impact, possibly because neither group was following a diet. After training, we observed a significant increase in the psychosocial impact dimension of QoL, which may signify the start of improvement, although no significant change in total QoL or other dimensions was observed and the difference with healthy men was still significant after training. This result is in contrast with the findings of previous studies, which reported an increase in total QoL after a training period in men having several metabolic risk factors [19, 20]. However, these studies investigated Tai Chi and Qigong exercises [19] and resistance training [20] over longer durations and evaluated QoL with a generic questionnaire (Short Form-36). The difference in training protocols could explain the discordance between the results. Moreover, the scores for QoL dimensions in our population seemed to be better than those presented by Ziegler et al. [27], and this smaller alteration in our patients could explain the lower improvement after exercise training.

We used saliva samples to study the effect of exercise training on steroid hormone alterations. This is a practical and noninvasive method and sampling can be done in a variety of situations, without the stress of venopuncture and with high correlations with free blood steroid hormones [36, 37]. Curiously, no previous studies have used this procedure to evaluate the effect of exercise training on steroid hormone alterations in abdominally obese diabetics. We noted significantly lower saliva concentrations of DHEA and testosterone in the obese diabetic men compared with the healthy men at the start of the experiment, with no difference in saliva cortisol concentration between the 2 groups. This finding agreed with the reports of previous studies in type 2 diabetic or obese men [3–5, 38–40]. Indeed, the implication of cortisol in hypertension, abdominal obesity, and glucose intolerance was found to be due more to a dysregulation of peripheral cortisol metabolism [41]. No modification in saliva DHEA was observed after aerobic training. This result contrasts with the findings of Boudou et al. [15] in middle-aged (46.8 ± 7.7 years) type 2 diabetic men. They observed an increase in plasma DHEA after 8 weeks of the same type of training (continuous and interval training), although they proposed no explanation for this change. We also observed no change in saliva testosterone after aerobic training, in agreement with other studies in type 2 diabetic [5, 16] or overweight men [14]. Last, we observed no significant modification in saliva cortisol after the training program, although a trend toward decrease was noted. This result agrees with earlier studies in the general obese or overweight population with [14, 16] or without [13] weight loss, but contrasts with the aforementioned study of Boudou et al. [15], who reported an increase in cortisol.

In conclusion, these data suggest that an 8-week program of aerobic exercise training improves physical capacity and quality of life in obese diabetic men, but does not modify the anthropometric and hormonal alterations. Further work with longer training programs or weight loss is now required to complete these findings.

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