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Can age influence the energy demands of the elite athlete during high intensity exercise?
Poate vârsta să influenţeze cererea energetică a sportivului elită în timpul efortului de mare intensitate?

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Abstract

Background. The nutritional recovery of elite athletes is influenced through the work performed, food intake and active recovery.

Aims. Identifying differences regarding the energy resource used during maximal effort according to age in a group of female rowers.

Methods. A transverse observational study was conducted between January and March 2016, on two groups consisting of 25 elite female rowers, included in the study according to age and competition level. The study took into account the menstrual cycle of the female athletes between January-March 2016, before the VO_{2max} test. The VO_{2max} test was performed using Cosmed Quark CPET equipment and a Concept 2 ergometer, over a distance of 2,000 m, under standard conditions, indoor.

Results. Statistically significant differences were found regarding the distribution of energy through ATP+CP (p=0.0085, 95%CI=-5.225 to -0.8523) and the use of energy substrate represented by muscle glycogen (p=0.0135, 95%CI=-85.65 to -10.98). Thus, the total 2,000 meters race completion time in G1 was 409.8±17.19 s (23.08±3.30 years), with a ratio of muscle glycogen activation, based on the RER value, of 303.7±53.93 s. In the G2 group (19.25±1.35 years), the total activity time reached was 432.3±6.81 s. with a muscular glycogen energy distribution of 352.0±32.80 s.

Conclusions. Increased time spent in maximum effort will increase the proportion of carbohydrates used during activity. However, the final ratio and the link between age and the respiratory exchange ratio, whose value reaches the upper limit, along with O_{2exp} and carbohydrate or lipid determinations, suggest an increased carbohydrate consumption during maximal effort, related to a low age, and a high monitored respiratory exchange ratio ≥1.1.

Key words: age, rower, macronutrients, RER, glycogen.

Rezumat

Premize. Recuperarea energetică a sportivului elită va fi influențată de activitatea prestată, ingestia alimentară și recuperarea activă programată.

Obiective. Identificarea diferenţelor privind resursa energetică utilizată pe parcursul efortului şi implicațiile asupra activității susținute în funcţie de vârsta sportivului.

Metode. A fost desfăşurat un studiu transversal observaţional, în perioada ianuarie-martie 2016, pe două grupuri elită din canotaj (25 de sportive), incluse în studiu în funcţie de vârstă şi nivelul competiţional. Studiul a prevăzut monitorizarea ciclului menstrual în perioada premergătoare testărilor VO_{2max} (ianuarie - februarie) susținute prin utilizarea aparaturii Cosmed Quark CPET şi a ergometrului Concept 2, pe parcursul unei distanțe standard de 2,000 m, în condiții standard, indoor.

Rezultate. Au fost identificate diferenţe semnificativ statistice privind distribuția energetică prin ATP+CP (p=0,0085, CI95%=-5,225 la -0,8523) și utilizarea substratului energetic reprezentat prin glicogen muscular (p=0,0135, CI95%=-85,65 la -10,98). Astfel, timpul total de finalizare a cursei de 2,000 de metri, în cadrul celor două grupuri a fost de 409,8±17,19 s în cadrul G1 (23,08±3,30 ani), cu un raport de activare al glicogenului muscular, pe baza RER, de 303,7±53,93 s. În cadrul grupului G2 (19,25±1,35 ani), timpul total de activitate a atins 432,3±6,81 s, cu o distribuție energetică a glicogenului muscular de 352,0±32,80 s.

Concluzii. Creşterea timpului petrecut în efort maximal va mări proporția de carbohidrați utilizați pe parcursul acestuia. Însă, raportul final și legătura dintre vârstă și rata de schimb respirator, a cărei valoare atinge limita superioară, alături de nivelul O_{2exp} și determinările de carbohidrați, respectiv lipide, sugerează o creştere a aportului de carbohidrați în angrenajul unui efort maximal la vârstă redusă, fiind atinsă o rată de schimb respirator ≥1,1.

Cuvinte cheie: vârstă, canotori, macronutrienți, RER, glicogen.

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Introduction

Basic dietary elements are essential in ensuring body development, the athlete's energy requirements, health status, and exercise efficiency during a specific period of time (Hoch et al., 2008). Many studies have researched the factors which influence physiological parameters during endurance effort in older age groups (Reaburn & Dascombe, 2008; Tanaka & Seals, 2003), reporting elements that influence the glycolytic energy pathway during specific anaerobic effort. Thus, it is often mentioned that maximal effort is characterized by the athlete's capacity to sustain such effort between 10 and 100 seconds. From a biochemical perspective, it will be associated with adenosine triphosphate (ATP) resynthesis through creatine kinase (CK), with glycogenolysis and glycolysis, based on the biochemical lactate system (Reaburn & Dascombe, 2009). Thus, the body's ability to adapt and perform in such effort is also influenced by several factors. Among them, the following factors are often mentioned in the literature: gender, muscle mass, type of muscle fiber, size of muscle fibers, muscle mass and strength, energy substrate availability, metabolic pathway efficiency, accumulation of reaction products, and contribution of energy systems, heredity, including effort parameters, namely the level of training (Reaburn & Dascombe, 2009).

From a practical standpoint, the differences between male and female groups are defined in the specialty practice. Thus, male groups seem to impose a higher rate of performance during activities with oxygen debt or during anaerobic exercise tests (Weber & Schneider, 2002). These differences were often set to 25% between male and female athletes during controlled activities (McCartney et al., 1986). From this point of view, the energy substrate used by female activity groups must be studied separately (Isacco et al., 2012). Stressors, both physical and psychical, through the complexity of effort carried out by female athletes can be related to hormonal imbalances, involving menstrual imbalance (Marcus et al., 2001; Martin & Tomescu, 2016a). From this point of view, current works suggest the influence of the energy system over a distinct period of training, taking into account that the increased value of estrogen in the luteal phase decreases the utilization of carbohydrates during exercise, stimulating the validity and usability of fatty acids and improving athletic ability during endurance exercise (Uranga et al., 2005).

Hypothesis

Age differences established between elite athletes tend to alter the perception of the effort performed at different stages of the competition season. This aspect was determined based on the athlete's recovery capacity, a reduction in the total recovery time being shown for young athletes. However, the study conducted claims that in the case of the youth group, unlike the senior group, the anaerobic activation system is different, with a possible increase in the respiratory exchange ratio, accessing more quickly, and in a greater proportion, carbohydrates during exercise. In a long-term action, following sustained activity in an upper cardiac zone, metabolic imbalances can be reported, limiting the programmed activity.

Material and method

Research protocol

A transverse observational study was conducted after obtaining the approval from the Ethics Committee of the university and the verbal consent of the informed subjects to participate in the study. In this paper, we monitored the athlete's perception and performance based on the age of the individual during a maximal effort carried out over a standard distance of 2,000 meters, during a rowing race simulation, performed indoor.

a) Period and place of the research

The study was conducted between January and March 2016, in Bucharest, Romania, in two different training centers where the athletes performed their weekly activity.

b) Subjects and groups

A total of 25 female rowers were included in the study. Their distribution in study groups was made according to their age. Thus, G1 corresponded to a group of elite female rowers with a mean age of 23.08±3.30 years, 182.7±3.98 cm height and 74.48±5.85 kg body weight. G2 corresponded to a group of elite female rowers with a mean age of 19.25±1.35 years, 180.3±3.82 cm height and 71.33±3.79 kg body weight.

c) Test applied

Two VO_{2max} tests were carried out by the two groups of subjects involved in the study (one test for each group). Previously, the menstrual cycle of the female athletes was monitored in direct association with the VO_{2max} test. As a result, the February – January period revealed the menstrual phase for both study groups. Measurements were performed using Cosmed Quark CPET equipment, and a Concept 2 ergometer, by conducting a VO_{2max} test over a standard rowing distance of 2,000 without imposing a time limit for completion, or an effort developed in different intensity stages. The VO_{2max} test was performed after preparatory work conducted in order to adapt the body to exercise. This phase was conducted over 25 minutes, involving both basic elements in preparing the body for a VO_{2max} test, and ergometer specific activity at a predetermined intensity (65-85% HR) in order to technically simulate the effort which would have been performed. Auxiliary parameters such as heart rate were transmitted via a Cosmed heart rate band through Bluetooth, to the main device.

During the measurements, the following parameters were monitored: heart rate (HR - bpm), respiratory exchange ratio (RER), respiratory frequency (Rf), minute ventilation (VE - l/min), maximum rate of oxygen consumption (VO_2 - ml/ min), metabolic equivalent (METS), tidal ventilation (VT - l), the amount of oxygen expired (O_{2exp} - ml), amount of carbon dioxide expired (CO_{2exp} - ml), end-tidal oxygen tension ($PetO_2$ - mmHg), end-tidal carbon dioxide tension ($PetCO_2$ - mmHg), energy expenditure (Kcal/min), lipid consumption (fat - g%) and carbohydrate consumption (CHO - g/%). The respiratory exchange ratio (RER) was used in order to divide the energy systems (ATP, ATP+CP, muscle glycogen).

d) Statistical processing

Statistical evaluation was performed using the GraphPad Prism 7.0 software. The statistical indicators used were: average value (mean), standard deviation (SD),

Table I
Classification of menstrual cycle phases during the testing period for group G1.

General data	Menstrual cycle (29.46±2.72 days)		Ovulation (14.08±1.32 days)		Menstruation (5.53±1.12 days)	
Menstrual phase	Follicular	Ovulatory	Luteal	Menstrual	Amenorrhea	Total number
Number of athletes	4	0	3	6	0	13

Table II
Classification of menstrual cycle phases during the testing period for group G2

General data	Menstrual cycle (28.42±10.27 days)		Ovulation (13.92±5.03 days)		Menstruation (4.58±1.97 days)	
Menstrual phase	Follicular	Ovulatory	Luteal	Menstrual	Amenorrhea	Total number
Number of athletes	3	0	6	2	1	12

and coefficient of variation (CV). Data were expressed as mean value and standard deviation (mean±SD). For data normalization, the Shapiro-Wilk test (w) was used. In order to demonstrate the association's type hypothesis, we applied Pearson's correlation (r), and in order to determine the differences between the study groups, we applied the Student t-test (unpaired). The level of significance $p<0.05$ was considered statistically significant.

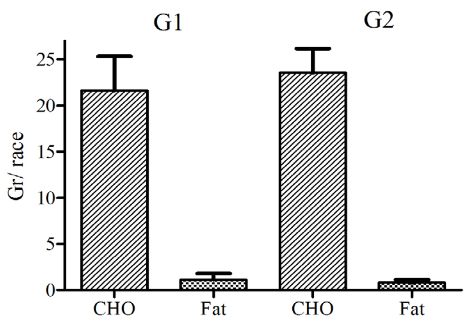
Results

Group G1 consisted of 13 elite female rowers with a reported average age of 23.08±3.30 years, 182.7±3.98 cm height, and 74.48±5.85 kg body weight. The average completion time of the 2,000 m race simulation, performed on the ergometer, was 409.8±17.19 seconds, with a 4.19% coefficient of variation (CV) and a uniform distribution throughout the menstrual cycle (29.46±2.72 days), as shown in Table I.

Based on O_{2exp} consumption, production of CO_{2exp}, and RER value, the total ATP (adenosine triphosphate), CP (phosphocreatine), as well as muscle glycogen activity was estimated. Thus, muscle ATP was active in group G1 for 10.46±2.66 seconds, while ATP+CP was active for 104.8±54.81 seconds, a period characterized by ATP resynthesis and lipid utilization as an energy resource. However, the contribution of muscle glycogen was established in time units at 303.7±53.93 seconds during the 2,000 m race simulation, the estimation of fat and carbohydrate consumption during the race being possible (Fig. I).

Group G2 consisted of 12 elite female rowers with an average age of 19.25±1.35 years, 180.3±3.82 cm height and 71.33±3.79 kg body weight. The average completion time during the 2,000 m race simulation was 432.2±6.81 seconds, with a 1.58% coefficient of variation. The group had a different distribution of the menstrual cycle than group G1 (Table II).

The average activation time for muscle ATP was 13.50±2.61 seconds, while in the case of ATP+CP we identified a total activation time of 80.28±29.48 seconds, lower than the value determined in group G1. At the same time, the distribution of energy through muscle glycogen, representing carbohydrates, was estimated to a total of 352±32.8 seconds, associated with a high proportion of time spent in effort. Energy costs rose to a value of 103.2±10.65 kcal, in relation to a CHO consumption of 23.55±2.62 g and 0.80±0.32 g fat consumption over the 2,000 m race simulation (Fig. 1).



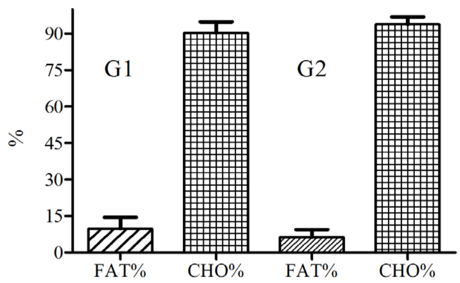


Fig. 1a, b – Macronutrient distribution in the two groups during the 2,000 m race simulation.

For the analysis undertaken in the study groups, we identified statistically significant differences concerning total ATP+CP activation time ($p=0.0085$), an increase in group G1 being identified. However, the contribution of muscle glycogen, in the present study, increased in G2 compared to G1 ($p=0.0135$), without any difference in the total energy consumption during exercise ($p=0.3270$). Regarding respiratory parameters, VO_2 had a favorable value in the case of group G1 compared to group G2 ($p=0.0152$), but without a statistical difference being identified between the two groups regarding parameters such as VCO_2, VE/VO_2, VE/VCO_2, METS, VT, O_{2exp}, CO_{2exp}, $FetO_2$, $FetCO_2$. The respiratory exchange ratio (RER) underwent an increase in group G2, without being statistically significant (Table III).

Table III

Comparative data between G1 and G2 regarding cardiorespiratory evolution over 2,000 m

Parameter	G1	G2	*p*	*t*	R squared	95% Confidence Interval of the Difference	
						Lower	Upper
Muscular ATP (s)	10.46±0.73	13.50±0.75	*0.0085	2.876	0.2645	-5.225	-0.8523
ATP+CP (s)	104.8±15.20	80.28±5.51	0.1826	1.374	0.07590	-12.38	61.39
Muscle glycogen (s)	303.7±14.96	352.0±9.46	*0.0135	2.677	0.2376	-85.65	-10.98
Kcal/race (kcal)	98.96±2.93	103.2±3.07	0.3270	1.002	0.04179	-13.05	4.538
CHO/race (g)	21.63±1.02	23.55±0.75	0.1527	1.479	0.08684	-4590	0.7634
Fat/race (g)	1.124±0.18	0.80±0.09	0.1526	1.480	0.08961	-0.1273	0.7667
VO_2 (ml/min)	3740±74.28	3471±70.23	*0.0152	6.624	0.2304	56.94	481.7
VCO_2 (ml/min)	3943±81.90	3729±88.31	0.0887	1.778	0.1208	-35.03	462.6
VE (ml/min)	118.6±3.39	115.5±3.44	0.5290	0.6393	0.01746	-6.826	13.12
METS	14.36±0.34	13.94±0.31	0.3770	0.9008	0.03408	-0.5476	1.392
VT (l)	2.078±0.08	2.130±0.06	0.6405	0.4732	0.009644	-0.2769	0.1738
O_{2exp} (ml)	354.3±14.73	367.0±12.32	0.5191	0.6548	0.01830	-52.77	27.40
CO_{2exp} (ml)	85.96±3.16	85.80±3.01	0.9719	0.03558	0.0000	-8.913	9.225
$PetO_2$ (mmHg)	110.7±0.62	113.0±0.76	*0.0310	2.298	0.1867	-4.292	-0.2249
Fat (%)	9.78±1.28	6.30±0.91	*0.0408	2.168	0.1696	0.1583	6.799
CHO (%)	90.32±1.27	93.76±0.90	*0.0404	2.172	0.1702	-6.729	-0.1638

*Statistically significant (p<0.05)

The contribution of muscle glycogen associated to a RER value ≥1.0 within the study group increases in association with a reduced average age - G2 - (p=0.0004, r=-0.6576, 95%CI=- 0.8356 to -0.3545). Due to these changes, the total consumption of energy during a race seems to be higher in the medium-low age groups, being influenced by the total time spent in effort (p=0.0187, r=-0.4665, 95%CI=-0.7276 to -0.08739). At the same time, total carbohydrate consumption in the study group is superior in the medium-low age groups - G2 - (p=0.0041, r=-0.5541, 95%CI=- 0.778 to -0.2034), while total fat consumption during the 2,000 m race simulation seems to increase with age (p=0.0270, r=0.4418, 95%CI=0.05641 to 0.7126) (Figure II).

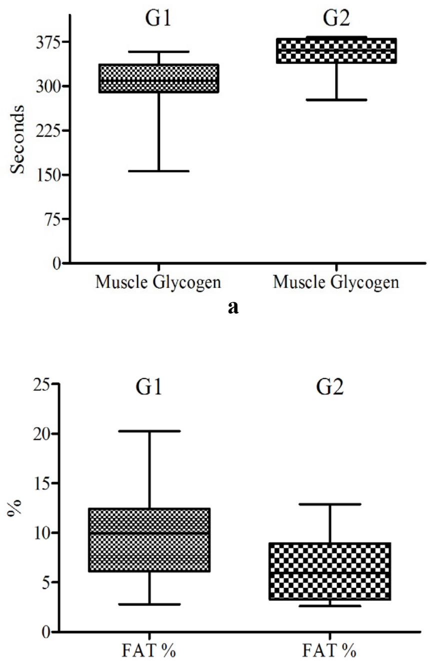


Fig. 2 a, b – Illustration of statistically significant differences in total carbohydrate and fat ratio during the race.

The overall performance time was recorded in the study group G1 (p=0.0027, r=-0.5745, 95%CI=-0.7903 to -0.2319). At the same time, the energy cost of the ≥22 age group appears to be low. It can be noted that the total ATP+CP activation time tends to increase with age in athletes (p=0.0091, r=0.5107, 95%CI=0.1447 to 0.7538). Thus, carbohydrate intake decreases during the race in group G1, while it increases in group G2 (p=0.0041, r=-0.5541, 95%CI=-0.7788 to -0.2034), along with a directly proportional increase with age in total fat consumption (p=0.0270, r=0.4418, 95%CI=0.05641 to 0.7126). The respiratory exchange ratio, representing a direct indicator of energy balance in the study group, increases in conjunction with a low age, the most elevated values being encountered in group G2, with a reduction in group G1 (p=0.0236, r=-0.4512, 95%CI=-0.7183 to -0.06818).

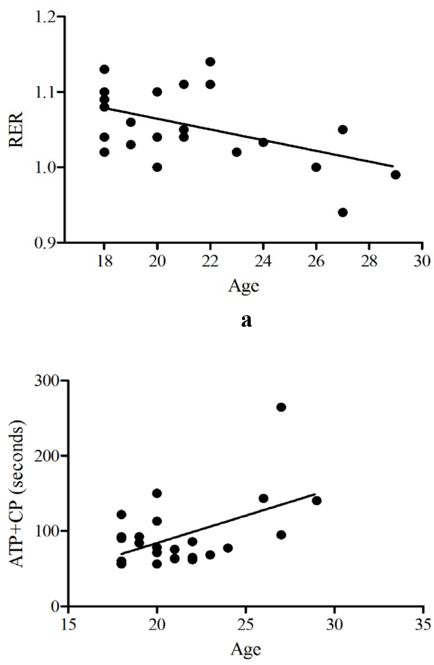


Fig. 3 a, b – Adaptation of respiratory parameters directly related to age (G1-G2).

Discussion

The adjustment and modification of human metabolic parameters is influenced through training, its status and planning within the competitive season. Both the aerobic capacity (McNarry & Jones et al., 2014) and the anaerobic capacity of junior and youth athletes are trainable, with differences according to age and level of training (Matos et al., 2007).

This study confirmed, in this sample of athletes, the hypothesis according to which the junior and youth categories of athletes have a higher glycolytic capacity, the body reaching an elevated RER during specific maximal effort, compared to senior athletes. All changes may be dictated by the VO_2 value and how it affects energy metabolism (Bishop et al., 2002), adapting the body's ability to use various energy sources during exercise. The VO_2 difference between the two groups, G1 (3740 ml/min) and G2 (3471 ml/min), imposed an increase in carbohydrate consumption in group G2, which had a lower average age (19.25±1.35 years) than group G1 (23.08±3.30 years), which at a superior VO_2 value had an increase in fat consumption during the race, in the first 60 seconds spent in effort. Moreover, research conducted until now emphasizes a possible VO_{2max} value reduction for junior and young female athletes due to fat mass changes in the period before puberty (Baxter-Jones et al., 1993). The specificity of anaerobic effort, in oxygen debt, imposes a series of physiological changes. Thus, anaerobic effort is characterized by acidity; as a result, the body's ability to perform a new effort at a similar intensity, appropriate to the body's maximum capacity (Martin et al., 2016), will be reduced for the following 70 hours after the completion of the initial effort. From a practical standpoint, the body's acidity during effort can be buffered by the athlete's aerobic capacity.

In association with the results obtained, a series of parameters may be included. Thus, gas exchange occurring at cellular level, where both O_{2exp} and CO_{2exp} will run at mitochondrial level, depending on the quality of the exchange and the products, will influence the respiratory exchange rate and the final amount of energy required by the actual effort (Qureshi, 2014). Such changes will be associated with the accumulation of lactic acid, a reduction in muscle pH, along with an increase in $PetO_2$ and a reduction in $PetCO_2$. Also, conducting a prolonged effort at an RER value ≥1.10 is often associated with a significant increase in lactic acid, which could compromise the effectiveness and continuity of the effort through acid-base imbalances and total activity imbalance (Martin & Tomescu, 2016b). Thus, junior and youth athletes have a higher ability to adapt during effort, having a proper buffering capacity, due to the growth process and increased development efficiency, reducing the acidity that the body produces during maximal effort. From a practical standpoint, the transition of athletes during different training seasons, and the activity performed alongside the maximal effort will define specific competitive effort. As a result, the energy system based on lactic acid, specific to a maximal effort, represents the glycolytic pathway energy supply formula during which ATP production will occur in the muscles after an incomplete degradation of carbohydrate in two moles of lactate (Gropper et al, 2013), an action that can be amplified in the junior-youth groups compared to senior groups, whose glycolytic system may be reduced due to buffering capacity. Moreover, the capture of a small amount of oxygen in ATP synthesis is identified in group G1, but this action will not hold the supply of energy (Baker et al., 2010; Buford et al., 2007), and at the same time phosphocreatine hydrolysis will not be dependent on the presence of oxygen; so ATP resynthesis will be continued during the effort, as long as this energy source will meet the demands imposed by the body and the level of phosphocreatine will be increased, the process of carbohydrate distribution taking place to support the effort conducted.

The actions referred to are dependent on the VO_2 value and aerobic capacity; thus, the adaptability of young athletes will be effective with the provision of energy, based on a high respiratory exchange ratio and a dependent carbohydrate use during effort, with a reduction of lipid substrate, in ATP and phosphocreatine resynthesis, in groups with a low adaptation capacity to exercise, along with the buffering compounds produced during effort. However, a program that provides frequent maximal efforts in youth and junior athlete groups will be associated with hastened training and lack of efficiency regarding the body's adaptation in later training stages of elite athletes.

Conclusions

1. In the study group, we reported an increased respiratory exchange ratio for subjects with younger ages, changing the energy substrate and macronutrient distribution including total energy costs during the 2,000 m race simulation.
2. Increased time spent in maximum effort will increase the proportion of carbohydrate during its use. However, the final ratio and the link between age and the respiratory exchange ratio, whose value reaches the upper limit, along with O_{2exp} and carbohydrate or lipid determinations, suggest an increased carbohydrate consumption during maximal effort, related to a smaller reported age, and a high monitored respiratory exchange ratio ≥1.1.
3. ATP or CP product transition was reduced in group G2, with a slight increase in group G1. The increase of these parameters, in time units, was associated with an elevated VO_2 value, and with possible considerations regarding mitochondrial and energy system efficiency.
4. The measurements completed in group G2 showed that the group had an increased glycolytic capacity in association with oxygen debt, thus, theoretically it may be possible to identify a certain elevated lactate value.
5. Metabolic costs during maximum effort are increased in group G2 compared to group G1, being associated with an increased VO_2, a higher aerobic capacity and a lower buffering capacity, but a longer recovery time, unlike in group G2, in terms of age and physical adaptation.

Conflicts of interest

There are no conflicts of interest regarding the results, methods and conclusions submitted.

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