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BIOELECTRICAL IMPEDANCE ANALYSIS OF BODY COMPOSITION AND MUSCLE MASS DISTRIBUTION IN ADVANCED KAYAKERS

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ABSTRACT
Purpose. The study aims at assessment of body composition and muscle mass distribution in advanced kayakers. Kayak paddlers should be characterized by large body mass with a significant percentage of muscle mass, especially in the trunk region. **Basic procedures.** The sample consisted of 26 kayakers. The body composition and muscle mass distribution were determined based on bioelectrical impedance analysis. **Main findings.** The subjects had large muscle mass and average fat mass. The percentage of body fat mass in the kayakers was observed to increase with age, whereas the muscle mass percentage decreased, with the exception of the limbs. **Conclusions.** BIA of body composition and distribution of muscle mass should be a standard diagnostic method to collect data on proper adaptation of kayakers to their training programs.

Key words: body composition, anthropometry, muscle mass, kayak, bioelectric impedance

Introduction

The body build of athletes is one of the key subjects of physical education and sport sciences. On the basis of the body build profile of athletes the most desirable body parameters for a particular sport can be determined that would ensure attainment of the highest sports results.

Numerous studies [1–7] have isolated the most significant morphological traits characteristic of kayakers. These traits include large body mass, strong muscles and solid skeleton. The upper body build in kayakers is commonly recognized as one of the most important parameters affecting their sports results [2, 7, 8]. They should also be taller than average. Both male and female kayak paddlers have a low percentage of adipose tissue: 13% ± 2.5 and 22.2% ± 4.6, respectively [9]. Similar observations were made by Van Someren and Palmer [10] in their study of U.S. Olympic kayakers and Akca and Muniroglu [11] in their study of the Turkish Olympic team. A similar body build profile was noted in boy and girl kayak paddlers at all training and competition stages [7].

Body build parameters indicative of training effectiveness and athlete selection in kayaking include body composition and muscle mass distribution. There have been a number studies examining somatotypes and basic anthropometric profiles in elite kayakers [2, 7, 10–13]. However, no results of muscle mass measurement using bioelectrical impedance analysis (BIA) or segmental analysis have been published so far. Neither data on changes in body components or assessment of regional body composition are available.

The present study was aimed to assess the basic body components of kayakers with the use of BIA and profiles of regional muscle mass distribution. In particular, the study focused on the assessment of the age-related range and direction of changes in somatic build and muscle mass distribution in kayak paddlers.

It was assumed that changes in kayakers' body build are indicative of the athletes' proper adaptation to kayaking-specific training loads. The following research hypotheses were formulated:

1. Kayakers feature large muscle mass and lower adiposity in comparison with athletes representing other sports.
2. Kayakers' muscle mass and its percentage in the total body mass increase with age.
3. The most considerable gain in muscle mass can be observed in kayakers' trunk muscles.

Material and methods

The study sample consisted of 26 young competitive kayakers from the Wałcz Sports School and AZS–AWF

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Sports Club in Gorzów Wielkopolski, Poland. With regard to their sports level the subjects represented four kayaking sports classes (sports class II, sports class I, championship sports class, international championships sports class) (Tab. 1). For the purpose of the study all the subjects were divided into two age groups: seniors and juniors. The mean age for senior kayakers was 20.3 ± 1.41, and for junior kayakers 16.5 ± 1.01 (Tab. 2). The senior kayakers in the sample included six members of the Junior Polish National Team and one member of the Senior Polish National Team. In the group of juniors one kayaker was a member of the Junior Polish National Team.

The study was approved by the Bioethical Committee of the Karol Marcinkowski University of Medical Sciences in Poznań, Poland.

The subjects' body weight and body height were measured using standard anthropometric procedures and instruments.

The kayakers' body composition was assessed using bioelectrical impedance analysis with the BIA 101 analyzer (Akern, Italy) [14]. BIA is a highly accurate assessment method which uses the measurements of reactance and resistance of the human tissue [14, 15]. The resistance was measured by a non-susceptible current (800 μA, 50 Hz).

The obtained reactance and resistance values as well as data on subjects' age, sex, body height and body weight were entered into the analyzer software for body composition analysis. The following body components were determined: FFM – fat-free mass (kg), FFMpct – fat-free mass percentage (%), FM – fat mass (kg), FMpct – fat mass percentage (%), MM – muscle mass (kg), MMpct – muscle mass percentage (%).

The human body reactance and resistance were also measured using the segmental analysis, which allowed calculation of muscle mass distribution in different regions of the body (in kg and %): RB – right side of the body, LB – left side of the body, LwB – lower body, UpB – upper body, RA – right arm, LA – left arm, RL – right leg, LL – left leg, TR – trunk.

Statistical analysis

The Statistica 8.0 software package (StatSoft, Inc. 1984–2008) was used for statistical analysis. Arithmetic means, medians and standard deviations were calculated. The level of statistical significance was set at $p < 0.05$. The distribution of variables was first checked with the Shapiro-Wilk test and the Lilliefors test. If any of these tests yielded a statistically significant result in one of the groups of subjects, the Mann–Whitney U test was applied to check for statistical significance of differences of a particular variable. Otherwise Student's t-test was used provided the equality of group variances was present which was checked with the Brown–Forsythe test. If the latter's result was statistically significant the significance of differences was measured with the Cochran and Cox test.

Results

Body composition analysis

Table 3 presents the results of measurement of the kayakers' body weight and body height as well as of their particular body components.

The subjects' body height amounted to 182.1 ± 5.31 cm for the juniors and 184.8 ± 6.7 cm for the seniors. These results are similar to those of Olympic sprint kayak paddlers from Sydney in 2000 [7]. The body weight in

Table 1. Sports levels of kayakers corresponding to the assigned sports classes: juniors (n = 17) and seniors (n = 9)

Kayaking sports class	Juniors	Seniors	Total
Sports class II	2	0	2
Sports class I	10	3	13
Championship sports class	5	5	10
International championship sports class	0	1	1

Table 2. Basic somatic parameters of junior (n = 17) and senior (n = 9) kayakers

	Juniors						Seniors					
	n	M	Med	Min	Max	SD	*n*	M	Med	Min	Max	SD
Age (years)	17	16.5	17.0	15.0	18.0	1.01	9	20.3	20.0	19.0	22.0	1.41
Body height (cm)	17	182.1	181.0	175.0	195.0	5.31	9	184.8	186.0	174.0	194.0	6.70
Body weight (kg)	17	79.0	78.0	70.0	90.0	5.85	9	84.6	86.0	71.0	97.0	8.41

Table 3. Mean values of body build components of junior (n = 17) and senior (n = 9) kayakers

	Juniors					Seniors				
	M	Med	Min	Max	SD	M	Med	Min	Max	SD
Body height (cm)	182.12	181	175	195	5.31	184.8	186.0	174.0	194.0	6.70
Body weight (kg)*	79.00	78	70	90	5.85	84.6	86.0	71.0	97.0	8.41
FFM (kg)	66.65	65.2	59.6	74.3	4.59	68.9	71.9	58.6	78.3	7.13
FM (kg)*	12.35	12.2	7.7	16.8	2.81	15.6	16.6	9.2	18.9	3.81
FMpct (%)*	15.6	16.3	10.5	19.8	3.0	18.4	20.1	11.1	22.3	4.00
FFMpct (%)*	84.4	83.7	80.2	89.5	3.0	81.6	79.9	77.7	88.9	4.00
MM (kg)*	45.61	45.1	36.8	51.5	3.21	50.1	50.1	42.2	57.1	5.41
MMpct (%)	57.8	57.2	52.5	64.5	3.2	59.3	58.8	54.5	64.8	3.46

FFM – fat-free mass, FM – fat mass, FMpct – fat mass percentage, FFMpct – fat-free mass percentage, MM – muscle mass (kg), MMpct – muscle mass percentage, *statistically significant difference at $p < 0.05$

Table 4. Mean values of muscle mass distribution in junior (n = 17) and senior (n = 9) kayakers

	Juniors					Seniors				
	M	Med	Min	Max	SD	M	Med	Min	Max	SD
RB (kg)*	20.6	21.4	15.7	23.6	2.4	23.3	23.5	21.3	26.4	1.6
LB (kg)*	20.4	20.8	14.7	24.4	2.2	23.3	23.1	20.4	26.7	2.2
LwB (kg)	19.6	19.9	14.2	24.6	2.5	22.3	22.8	19.8	24.7	1.7
UpB (kg)	21.4	22.2	16.2	25.6	2.6	24.3	24.1	21.6	28.4	2.6
RA (kg)*	1.3	1.2	0.2	3.2	0.9	2.8	3.0	1.9	3.7	0.8
LA (kg)*	1.3	1.2	0.4	2.8	0.7	2.2	2.6	1.1	3.1	0.8
RL (kg)*	4.0	3.9	1.7	6.8	1.3	5.4	5.3	3.8	7.3	1.4
LL (kg)*	3.2	2.9	1.1	7.5	1.8	6.3	5.9	4.2	8.7	1.5
TR (kg)	31.2	32.1	26.6	35.9	2.9	29.9	29.7	26.8	35.5	2.6
RB (%)	50.2	50.2	47.8	52.7	1.3	50.1	50.0	48.3	52.1	1.4
LB (%)	49.8	49.8	47.3	52.2	1.3	49.9	50.0	47.9	51.7	1.4
LwB (%)	47.6	47.8	42.9	53.1	3.1	47.9	47.4	43.5	51.3	2.6
UpB (%)	52.2	52.3	46.9	57.1	3.1	52.1	52.6	48.7	56.5	2.6
RA (%)*	3.0	2.7	0.6	7.2	2.0	5.9	6.3	4.5	7.5	1.3
LA (%)*	3.1	2.8	1.3	5.9	1.5	4.7	4.9	2.7	6.3	1.5
RL (%)*	9.4	9.7	5.2	14.5	2.4	11.5	10.8	9.0	14.9	2.3
LL (%)*	7.5	7.1	3.0	16.1	3.7	13.4	12.5	10.0	17.6	2.6
TR (%)*	76.9	78.2	56.8	88.2	9.2	64.5	66.8	54.5	73.7	7.0

RB – right side of the body, LB – left side of the body, LwB – lower body, UpB – upper body, RA – right arm, LA – left arm, RL – right leg, LL – left leg, TR – trunk, *statistically significant difference at $p < 0.05$

the senior kayakers was similar to the values attained by Ackland et al. [7] and amounted to 84.6 ± 8.41 kg. The junior kayakers had lower body weight than their senior counterparts (79 ± 5.85 kg), and the Student's t-test results pointed to a statistically significant difference. The Student's t-test results of the muscle mass (MM) assessment (45.6 ± 3.21 kg for juniors; 50.1 ± 5.41 kg for seniors) revealed a statistically significant difference with the subjects' age. Also a significant increase in fat mass (FM) was noted in the younger kayakers (12.35 ± 2.81 kg for juniors; and 15.6 ± 3.81 kg for seniors). In terms of percentage of particular body components, FMpct amounted to 15.6 ± 3% for juniors, and 18.4 ± 4% for seniors. These values are higher than the ones noted by Ackland et al. [7]; however, the body fat percentage in that study was assessed with skinfold tests. The BIA allows a more accurate measurement of total body fat than the skinfold methods [15], thus the results in the present study are higher than in Ackland et al. [7]. The U test revealed a significant difference in the percentage of body fat between the two groups of subjects.

Also larger fat-free mass (FFMpct) was noted in the junior kayakers (84.4 ± 3% as opposed to 81.6 ± 4% in the seniors). The difference was statistically significant. The differences in the percentage of muscle mass (MMpct) were statistically non-significant, and the mean MMpct values were 57.8 ± 3.2% for the juniors and 59.3 ± 3.46% for the seniors, respectively.

Table 4 presents the results of muscle mass distribution analysis in the kayakers. A statistically significant difference was found for the right side of the body (RB) and the left side of the body (LB): 20.6 ± 2.4 kg and 20.4 ± 2.2 kg for juniors, and 23.3 ± 1.6 kg and 23.3 ± 2.2 kg, respectively, which was related to the proportional increase in muscle mass on both sides of the body. An increase in the lower body muscle mass (LwB) was also noted (19.6 ± 2.5 kg in juniors, and 22.3 ± 1.7 kg in seniors, respectively) as well as a significant muscle mass increase in the limbs. In the case of arms the muscle mass value amounted to 1.3 ± 0.9 kg (RA) and 1.3 ± 0.7 kg (LA) in junior kayakers, and 2.8 ± 0.8 kg (RA) and 2.2 ± 0.8 kg (LA) in senior kayakers. A lower trunk muscle mass (TR) was also noted in the seniors as opposed to the juniors, but the difference was statistically non-significant.

The analysis of muscle mass distribution revealed a slight, non-significant difference between the two groups of kayakers in the percentage of the lower body muscle mass (LwB) (47.6 ± 3.1% in juniors, 47.9 ± 2.6% in seniors) and upper body muscle mass (UpB) (52.2 ± 3.1% in juniors, 52.1 ± 2.6% in seniors).

A significant difference in the percentage of muscle mass of the arms was found: 3.0 ± 2.0% (RA) and 3.1 ± 1.5% (LA) for juniors, and 5.9 ± 1.3% (RA) and 4.7 ± 1.5% (LA) for seniors. Statistical differences were also found in the percentage of muscle mass of the kayakers' legs. The juniors had a significantly lower percentage of muscle mass in the legs than their senior counterparts: 9.4 ± 2.4% (RL) and 7.5 ± 3.7% (LL) in juniors; and 11.5 ± 2.3% (RL) and 13.4 ± 2.6% (LL) in seniors. The analysis of the percentage of trunk muscle mass (TR) revealed a higher value of this parameter in the juniors (76.9 ± 9.2%) than in the seniors (64.5 ± 7.0%).

Discussion

The kayakers' total body mass was observed to increase with age including significant changes of their muscle mass (Fig. 1) and fat mass (FM) (Fig. 2). The increase of muscle mass confirmed its significance in achieving high sports results in kayaking [4, 7]. The percentage of particular body tissue components changed with kayakers' age. A statistically significant increase in fat mass was noted from 15.6% to 18.4% (Fig. 3) resulting in a decrease in fat-free mass from 84.4% to 81.6%. The percentage of muscle mass was

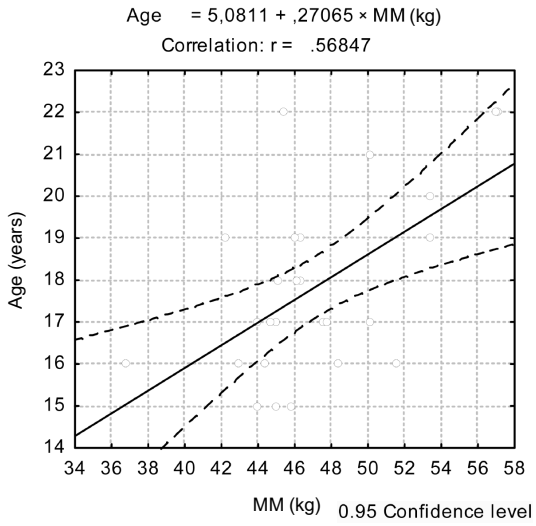

Figure 1. Kayakers' muscle mass (MM) and age (n = 26)

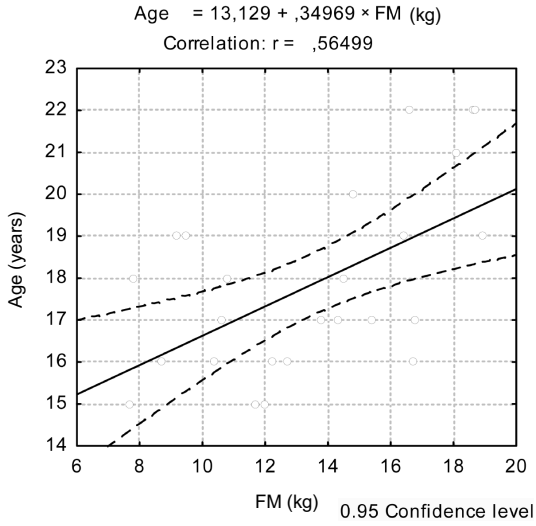

Figure 2. Kayakers' body fat mass (FM) and age (n = 26)

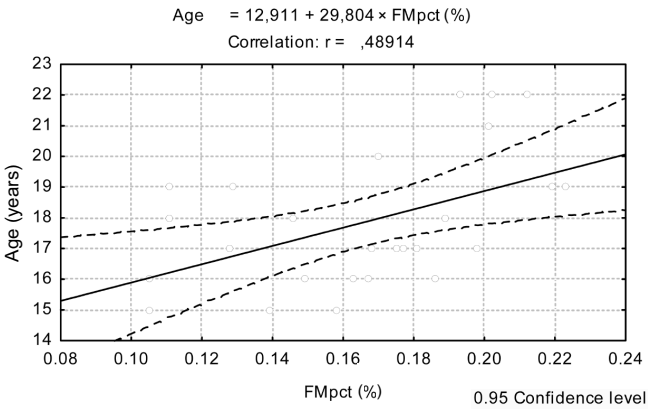

Figure 3. Percentage of body fat mass (FMpct) and kayakers' age (n = 26)

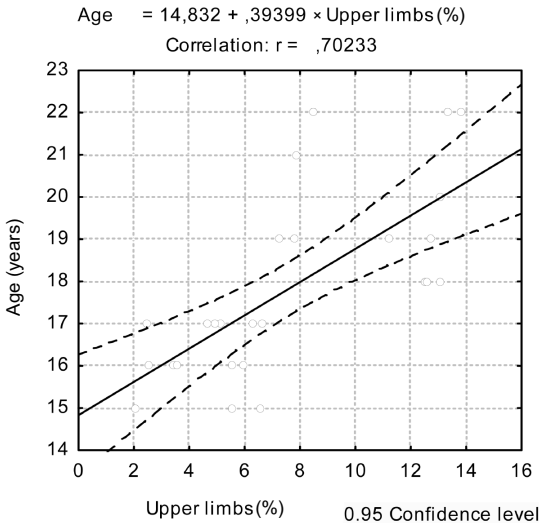

Figure 4. Percentage of muscle mass in the right arm (RA) and left arm (LA) and kayakers' age (n = 26)

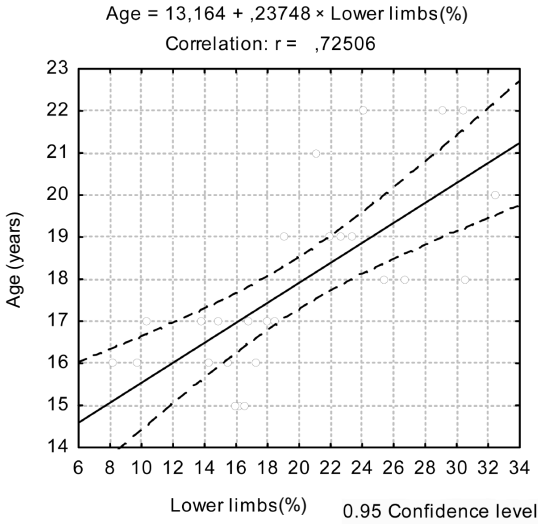

Figure 5. Percentage of muscle mass in the right leg (RL) and left leg (LL) and kayakers' age (n = 26)

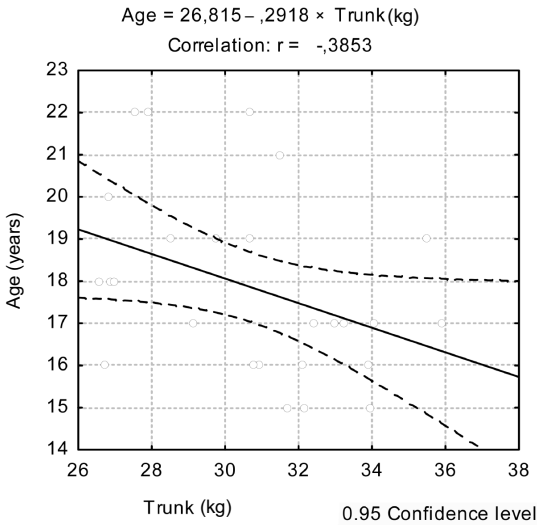

Figure 6. Trunk muscle mass (TR) and kayakers' age (n = 26)

not changed significantly. The noted significant increase in the kayakers' fat mass influencing the total body mass has an adverse effect on paddling speed [16]. The rapid increase in muscle mass (kg) caused by excessive amount of strength training and improper diet can also trigger larger accumulation of fat, which is highly undesirable in kayaking training. One should remember that the subjects were during the pre-season training stage during the measurements. Burke et al. [17] in their study of Australian Rules footballers revealed fat accumulation during the post-season and a significant increase in body fat in the pre-season period. On the other hand, Ostojic and Zivanic [18] observed a significant drop in fat mass only in the competitive period. Further studies into kayakers' body composition during different periods of their annual training cycle would definitely contribute to a more complete analysis of the changing percentage of particular body components.

The gain in muscle mass in the senior kayak paddlers was observed in their arms and legs (Fig. 4, 5). No statistically significant differences in the trunk muscle mass were found (Fig. 6). The juniors featured slightly higher results of measurement of this parameter than the seniors. According to Tesch [8], Fry and Morton [2], and Ackland et al. [7] the trunk muscle mass is one of the significant factors affecting sports results. Top level athletes are characterized by higher than average muscle mass of the trunk. The proportions in the study sample were not correct since the percentage of trunk muscle mass out of the total body mass in the senior kayakers was lower for over 13% (Fig. 7). Also insignificant dif-

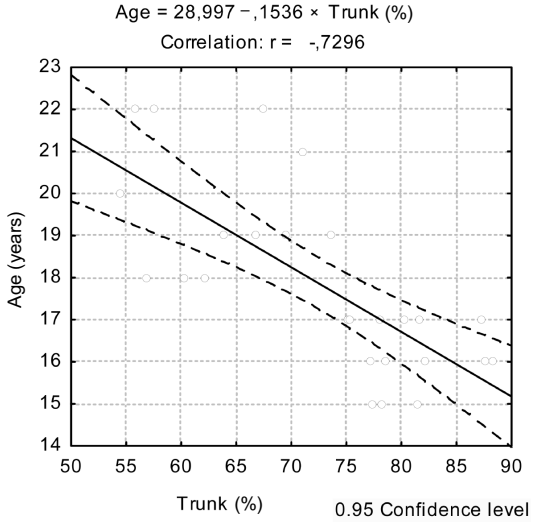

Figure 7. Percentage of muscle mass in the trunk (TR) and kayakers' age (n = 26)

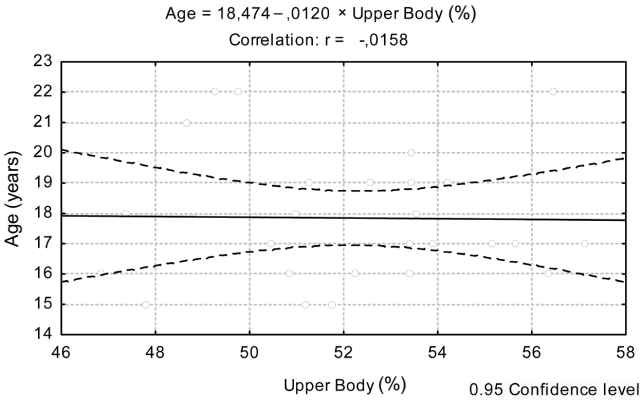

Figure 8. Percentage of muscle mass of the upper body (UpB) and kayakers' age (n = 26)

ferences were found in the proportion of the upper body muscle mass to lower body muscle mass between the juniors and seniors. The upper body muscle mass in the former was 0.1% bigger than in the latter (Fig. 8). This tendency can be a result of improper strength training of the senior kayakers, which can ultimately lead to a significant increase in the muscle mass of the limbs but not the trunk. Another cause could be focusing on the strength training of the lower and upper limbs to attain the highest possible sports results, especially over short kayaking distances. Akca and Muniroglu [11] showed a significant correlation between the biceps circumference and on-water performance of Turkish kayakers over the distances of 200 and 500 meters.

Conclusions

1. Kayakers have a significant body muscle mass and small mean body fat mass. An adverse tendency of growing percentage of body fat mass in senior kayakers was noted. It seems necessary to carry out measurements of body fat mass in different periods of the training cycle, in particular, during the competitive period.
2. Kayakers' gain in muscle mass with age and its percentage distribution tend to remain unchanged.
3. Senior kayakers featured a slightly smaller trunk muscle mass. Its percentage was significantly lower than in the group of junior kayakers. This tendency can be explained by the reliance of senior kayakers on strength training often unsuitable for the sport of kayaking.

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