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Sports intensity and energy consumption based on fractional linear regression equation

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Abstract

Objective

The objective is to analyse and explore the characteristics of physical exercise intensity, energy expenditure and substrate metabolism using Baduanjin and the ninth broadcast gymnastics as examples.

Methods

The indirect calorimetry of German CORTEX Metamax 3B portable gas met bolometer was used to determine the resting energy consumption of different age and sex of healthy people and related indexes such as the energy consumption and fat metabolism ratio in the ninth set of radio gymnastic exercises.

Results

The metabolic equivalents of Baduanjin and radio gymnastics were 2.68 and 5.07, and the average heart rate was 76.14 l/min and 97.3 l/min, which were higher than those at rest ($P < 0.01$). In radio gymnastics, the energy consumption level of men is higher than that of women ($P < 0.05$), but the proportion of fat metabolism of women is higher than that of men ($P < 0.05$). For 20–39 years old, when they are quiet, do Baduanjin and do radio gymnastics, the energy consumption of the subjects was 1828.7 kcal/d, 4008.8 kcal/d and 6355.6 kcal/d, respectively and for the ages of 40–59, they were 1822.6 kcal/d, 4047.4 kcal/d, and 8204.13 kcal/d, respectively. The ratios are significantly different; the energy consumption and fat energy supply ratio of the exercise group in the radio gymnastics group are significantly higher than those in the Baduanjin group, and the exercise group is significantly higher than that in the quiet group ($P < 0.05$); The heart rate and weight were calculated and the energy consumption equations of Ba Duan Jin and radio gymnastics were established. The equations have statistical significance.

Conclusion

Ba Duan Jin is a low-intensity exercise while radio gymnastics is a medium-intensity exercise; Comparing energy consumption and fat of Ba Duan Jin and the ninth set of radio gymnastics, the energy ratio of the energy consumption of the ninth set of broadcast gymnastics body was significantly higher than Baduanjin movement; linear regression equation can provide a scientific basis for daily exercise and sports training, thus can promote the national fitness plan.

Keywords: physical exercise intensity, energy expenditure, linear regression equation**AMS 2010 codes:** 15B99

1 Introduction

In recent years, with the acceleration of the pace of life and the improvement of living standards, as well as the ageing of China's population, people's attention to fitness and health-related aspects has also increased. To the masses of fitness exercises, the ninth set of radio gymnastics and Baduanjin are particularly popular among different groups of people and they play an important role in national fitness. At the same time, these two kinds of fitness sports have common advantages. There is no need to go to specific training venues. People exercise at different times and in different places. In terms of fitness effects, the two also have their own characteristics: Baduanjin focuses on conditioning of organs, qi and blood, and flexibility; the ninth set of radio gymnastics is a whole-body exercise, as well as its unique rhythm, collectiveness and era [1].

In China, there are many researches on Baduanjin and the ninth set of radio gymnastics, and there are many fields involved. In terms of physiology, there are many studies that take the either both or one of them as exercise interventions and observe the effects of the two on some physiological indicators. But, at first, these two kinds of sports are used as a kind of mass fitness method and most of the researches on them have some limitations on the research object as most of them are mainly college students. And in the selection of indicators, some physiological indicators have not been considered; most of the studies and the study of the ninth set of radio gymnastics focus on the history, characteristics and other aspects of sports. There are also studies on energy consumption, but the selected experimental objects and indicators also have shortcomings, and the research on energy consumption itself is less. Therefore, this article uses healthy people of different genders and older age spans as experimental objects to distinguish the past, explore the specific impact of these two sports on energy expenditure and its metabolic substrates, summarise their laws and establish corresponding regression equations based on the results and thus provide a certain scientific basis for mass fitness.

2 Research objects and methods

2.1 Research object

The total number of participants was 119, of which 57 were 20–39 years old (23 males and 34 females); 62 were 40–59 years old (14 males, 48 females). All subjects had no significant weight loss in the past 6 months, no anaemia, no metabolic or endocrine diseases and had normal cardiopulmonary function. Subjects signed informed consent before the experiment, and were then randomly divided into two groups: the Baduanjin group and the radio gymnastics group. The subjects are shown in Table 1.

Table 1 Stepwise regression process

	Baduanjin Formation		Broadcast operation group	
	20–39 (years) (n = 27)	40–59 (years) (n = 30)	20–39 (years) (n = 27)	40–59 (years) (n = 30)
Height (cm)	165.85±8.75	161.47±5.73	161.04±8.09	163.28±7.45
Weight (kg)	62.44±12.34	61.83±7.72	59.97±11.43	62.13±10.74

2.2 Research methods

The test is divided into two parts. The first part is the resting energy consumption (REE) test for the Baduanjin group and the radio gymnastics group; the energy test is performed during exercises.

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Exercise plan. Before the experiment, the subjects learned the technical skills of Baduanjin and the ninth set of radio gymnastics respectively under the guidance of the coach. They were required to complete a standard set of exercises alone.

Sports energy consumption. The exercise time of Baduanjin and the ninth broadcast gymnastics are 11 min and 4 min, respectively. When testing, the operation manual is strictly followed.

Experimental scheme. The resting energy consumption was measured indirectly using German CORTEX Meta-max 3B portable gas met bolometer. The subjects were informed and explained the precautions to be taken for the experiment 1 day before the experiment. With an empty stomach for 10–12 h, the subjects were placed in bed for more than 30 min before starting the test. The mask is worn for 5–10 min for its adaptation. After entering the resting state (within 5 min, the oxygen uptake fluctuation does not exceed 5%), the exhaled and inhaled gas are collected for 11 min, and the average value of 5–10 min is considered to calculate the static Energy consumption and related indicators. During the resting energy test, in order to exclude the effects of muscle activity, subjects should not move their limbs and remain quiet. The gas collection method and calculation of energy consumption related indexes during exercise are the same as the rest energy consumption test method [2].

Test environment. The room is equipped with a thermo-hygrometer (Acclr DWS 508C/D, Beijing), which records the temperature and humidity of the room. The test ambient temperature was maintained at 20–25 °C and the relative humidity was 60%.

2.3 Data processing and analysis

SPSS16.0 for Windows software was used to statistically analyse the experimental data. After normal distribution and homogeneity of variance test, paired sample t test was used for comparison within groups and independent sample t test was used for comparison between groups, and mean and standard deviation were shown in Table(x±s). The model for multiple linear regression analysis is

$$\begin{cases} y = \beta_0 + \beta_1 x_1 + \cdots + \beta_m x_m + \varepsilon, \\ \varepsilon \sim N(0, \sigma^2), \end{cases} \quad (1)$$

Among them: $\beta_0, \beta_1, \dots, \beta_m, \sigma^2$ is an unknown parameter that has nothing to do with $x_1, x_2, \dots, x_m$, and $\beta_0, \beta_1, \dots, \beta_m$ are called a regression coefficient. Now n independent observation data $[b_i, a_{i1}, \dots, a_{im}]$ are obtained, where b_i is the observation value of y , $a_{i1}, \dots, a_{im}$ is the observation value of $x_1, x_2, \dots, x_m$, and $i = 1, \dots, n$, $n > m$ is obtained by formula (1)

$$\begin{cases} y = \beta_0 + \beta_1 a_{i1} + \cdots + \beta_m a_{im} + \varepsilon_i, \\ \varepsilon_i \sim N(0, \sigma^2), \quad i = 1, \dots, n. \end{cases} \quad (2)$$

Remember

$$X = \begin{bmatrix} 1 & a_{11} & \cdots & a_{1m} \\ \vdots & \vdots & \cdots & \vdots \\ 1 & a_{n1} & \cdots & a_{nm} \end{bmatrix}, \quad Y = \begin{bmatrix} b_1 \\ \vdots \\ b_n \end{bmatrix}, \quad (3)$$

$$\varepsilon = [\varepsilon_1, \dots, \varepsilon_n]^T, \quad \beta = [\beta_0, \beta_1, \dots, \beta_m]^T,$$

Equation (6) is

$$\begin{cases} Y = X\beta + \varepsilon, \\ \varepsilon \sim N(0, \sigma^2 E_n), \end{cases} \quad (4)$$

where E_n is the identity matrix of order n .

The parameter $\beta_0, \beta_1, \dots, \beta_m$ in the model (1) is estimated by the least square method, that is, the estimated value $\hat{\beta}_j$ should be selected so that when $\beta_j = \hat{\beta}_j, j = 0, 1, \dots, m$, the sum of squared errors

$$Q = \sum_{i=1}^n \varepsilon_i^2 = \sum_{i=1}^n (b_i - \hat{\beta}_i)^2 = \sum_{i=1}^n (b_i - \beta_0 - \beta_1 a_{i1} - \dots - \beta_m a_{im})^2 \quad (5)$$

reached to a minimum. To this end, let

$$\frac{\partial Q}{\partial \beta_j} = 0, \quad j = 1, 2, 3, \dots, m,$$

Get the following equation

$$\begin{cases} \frac{\partial Q}{\partial \beta_0} = -2 \sum_{i=1}^n (b_i - \beta_0 - \beta_1 a_{i1} - \dots - \beta_m a_{im}) = 0, \\ \frac{\partial Q}{\partial \beta_j} = -2 \sum_{i=1}^n (b_i - \beta_0 - \beta_1 a_{i1} - \dots - \beta_m a_{im}) a_{ij} = 0, \quad j = 1, 2, \dots, m. \end{cases} \quad (6)$$

organised into the following normal equations:

$$\begin{cases} \beta_0 n + \beta_1 \sum_{i=1}^n a_{i1} + \beta_2 \sum_{i=1}^n a_{i2} + \dots + \beta_m \sum_{i=1}^n a_{im} = \sum_{i=1}^n b_i, \\ \beta_0 \sum_{i=1}^n a_{i1} + \beta_1 \sum_{i=1}^n a_{i1}^2 + \beta_2 \sum_{i=1}^n a_{i1} a_{i2} + \dots + \beta_m \sum_{i=1}^n a_{i1} a_{im} = \sum_{i=1}^n b_i a_{i1}, \\ \beta_0 \sum_{i=1}^n a_{im} + \beta_1 \sum_{i=1}^n a_{im} a_{i1} + \beta_2 \sum_{i=1}^n a_{im} a_{i2} + \dots + \beta_m \sum_{i=1}^n a_{im}^2 = \sum_{i=1}^n b_i a_{im}, \end{cases} \quad (7)$$

The matrix form of the normal equations is

$$X^T X \beta = X^T Y \quad (8)$$

When matrix X is full rank, X^T is a reversible square matrix, the solution of the formula is

$$\hat{\beta} = (X^T X)^{-1} X^T Y \quad (9)$$

Substitute $\hat{\beta}$ back to the original model to get the estimated value of y , and the fitted value of this set of data is

$$\hat{b}_i = \hat{\beta}_0 - \hat{\beta}_1 a_{i1} - \dots - \hat{\beta}_m a_{im}, \quad i = 1, \dots, n. \quad (10)$$

Let $\hat{Y} = X \hat{\beta} = [\hat{b}_1, \dots, \hat{b}_n]^T$ be the fitting error, $e = Y - \hat{Y}$ called the residual, which can be used as an estimate of the random error ε . The sum of the squares of the residuals is

$$Q = \sum_{i=1}^n e_i^2 = \sum_{i=1}^n (b_i - \hat{b}_i)^2 = 12.587$$

3 Experimental results

3.1 Exercise intensity of baduanjin and ninth radio gymnastics

As can be seen from Table 2, at rest, there were no significant differences in oxygen pulse, heart rate (HR), metabolic equivalents (METs) and breathing frequency between the Baduanjin group and the . The oxygen pulse, HR, METs and respiratory rate of radio gymnastic group were significantly higher than those in the Baduanjin group ($P < 0.05$). The oxygen pulse, HR, METs, and respiratory rate during exercise were significantly higher in both groups than when they were quiet ($P < 0.01$).

Table 2 Exercise Intensity of Baduanjin and Ninth Broadcast Gymnastics

	Baduanjin Formation		Broadcast gymnastics group	
	When quiet	During exercise	When quiet	During exercise
Oxygen pulse (ml)	3.55±1.08	5.94±1.69**	3.67±0.71	8.52±2.39**ΔΔ
HR (bpm)	76.14±8.32	97.3±10.65**	79.83±12.86	125.87±16.13**ΔΔ
METs	1.25±0.22	2.64±0.579**	1.39±0.25	4.99±0.85**ΔΔ
Respiratory rate (1/min)	16.22±3.86	21.56±4.23**	17.56±2.95	30.94±4.64**ΔΔ

Note: * $P < 0.05$, ** $P < 0.01$, compared with quiet time during exercise; Δ $P < 0.05$, ΔΔ $P < 0.01$, compared with the broadcast gymnastics group and the Baduanjin group.

HR, heart rate; MET, metabolic equivalents.

3.2 Energy consumption and substrate metabolism of different sex subjects

In the quiet state, men's fat energy, protein and energy expenditure (EE) are significantly higher than women's ($P < 0.01$), respiratory exchange rate (RER) is significantly lower than women's, and fat energy supply ratio is significantly lower than women. There was no significant difference in relative consumption (EE/kg). During exercise, the fat energy supply of men in the Baduanjin group was significantly lower than that of women ($P < 0.05$), and protein and EE were significantly higher than those of women ($P < 0.01$). Significantly; the protein and EE of males in radio gymnastics group were significantly higher than that of females ($P < 0.05$), and the proportion of fat energy was significantly lower than that of females ($P < 0.05$). Although other indicators such as sugar energy were different, they were not statistically significant as shown in Figure 1.

Fig. 1 Energy consumption and substrate metabolism of different sex subjects

3.3 Energy expenditure and substrate metabolism of subjects at different ages

In the quiet state, compared with 20–39 years old, the energy supply of sugar and EE/kg were significantly lower than those of 20–39 years old ($P < 0.01$). The proportion was significantly lower than that of 20–39-year-old subjects ($P < 0.05$). There was a difference in the fat energy supply and the mean EE, but there was no statistical significance. When the subjects in the Baduanjin group did exercise, the sugar energy supply, fat

energy supply ratio and RER were significantly lower than those in the 40–59-year-old subjects ($P < 0.05$), and there were no significant differences among other relevant indicators; when the subjects in the radio gymnastics group did exercise, for the 40–59-year-old age group, fat energy supply and fat energy supply ratio were significantly higher than those in the 20–39 age group ($P < 0.05$). Also there were very significant differences in protein, EE and EE/kg ($P < 0.01$) and there was no significant difference in sugar energy supply and RER as shown in Figure 2 [3].

Fig. 2 EE and substrate metabolism of subjects at different ages. EE, energy expenditure

3.4 Energy consumption before and after baduanjin and ninth broadcast gymnastics

As can be seen from Table 3, there was no significant difference between the resting energy consumption and related substrate metabolism indexes of the two groups of subjects. But sugar energy, fat energy, protein and fat supply during exercise are compared between the Baduanjin group and the radio gymnastics group, the energy ratio, EE, EE/ 1 kg and RER were significantly different from those at rest ($P < 0.05$). During exercise, compared with the radio gymnastics group, the participants in the Baduanjin group had significantly lower sugar energy than the radio gymnastics group ($P < 0.05$). The indicators of fat energy supply and fat function were very significant and moreover lower than the broadcast gymnastics group ($P < 0.01$) as shown in Figure 3.

Table 3 Energy consumption and metabolic substrate measurement results in different sports

	Baduanjin Formation		Broadcast gymnastics group	
	When quiet	During exercise	When quiet	During exercise
Energy for sugar (g/h)	7.76±4.49	14.34±9.92**	6.22±4.21	10.11±12.56*Δ
Fat for energy (g/h)	3.17±2.61	8.94±5.20**	4.83±2.21	23.16±7.93**ΔΔ
Protein oxidation (g/h)	2.66±0.66	6.18±1.65**	3.12±0.63	11.15±2.86*ΔΔ
Fat energy supply ratio (%)	39.00±27.74	47.93±24.91**	42.08±27.44	70.85±13.74**ΔΔ
EE (kcal/d)	1757.10±434.88	4029.10±1140.87**	2019.20±370.82	7309.68±1885.03**Δ
EE/kg(kcal/d/kg)	28.11±5.15	64.23±14.03**	33.64±5.94	119.24±20.48**ΔΔ
RER	0.87±0.17	0.85±0.14**	0.81±0.07	0.72±0.08**ΔΔ

Note: * $P < 0.05$, ** $P < 0.01$, compared with when quiet; Δ $P < 0.05$, ΔΔ $P < 0.01$, compared with the gymnastics group and Baduanjin group.

Fig. 3 Energy Consumption before and after Baduanjin and Ninth Broadcast Gymnastics

4 Analysis and discussion

4.1 Analysis of exercise intensity of baduanjin and ninth broadcast gymnastics

In this study, the METs of Baduanjin exercise was 2.68 ± 0.53 , and the ninth set of broadcast gymnastics METs was 5.07 ± 0.81 . MET is one of the indicators used to evaluate different exercise intensities. It is based on the energy consumption of the body when it is quiet and evaluates the energy consumption level of the body during exercise. According to ACSM and the US Centres for Disease Control's exercise measurement method, Baduanjin belongs to low-intensity exercise, and the ninth set of broadcast gymnastics belongs to medium-intensity exercise. Many studies have found that low- and moderate-intensity exercise is good for health, but exercise must be sustained. It has been reported that people who perform low- and moderate-intensity exercise for about seven hours per week have a mortality rate that is 24% lower than that of those who do not exercise.

In this experiment, respiratory rate, HR, oxygen pulse and METs increased significantly in Baduanjin and the ninth set of broadcast gymnastics. This shows that Baduanjin and the ninth set of broadcast gymnastics can increase lung ventilation by increasing breathing frequency, thereby improving myocardial oxygen supply and vascular function, and thus achieving fitness effects. Literature [4] research found that Health Qigong Baduanjin exercise can significantly increase the vital capacity index of the elderly, and has a positive effect on improving the elderly's lung function and respiratory function. The output and minute output increases, and the average arterial pressure decreases, indicating that Ba Duan Jin exercise can enhance myocardial contractility and cardiac ejection ability, improve vascular elasticity, help stabilise blood pressure and reduce blood pressure fluctuations. Zeng Yungui's research found that after 75 days of Health Qigong Baduanjin exercise, the subjects' minimum heart rate, maximum heart rate and average heart rate during exercise all declined to varying degrees compared to before exercise and improved cardiovascular function in the elderly. Zhao Qingjiang conducted a systematic study of the ninth set of radio gymnastics and found that its exercise intensity and energy expenditure are both at medium levels, which can adjust blood sugar, blood lipid and insulin levels, thereby improving the body's functional state [5]. Studies by Zhou Xinxin and others showed that the pulse rate of female college students showed a significant downward trend after the 15-week Baduanjin exercise, and the vital capacity was significantly higher than before the experiment. This is because the subjects' breathing rhythm during exercise combined with exercise movements. Master, cooperate with rectal breathing to increase breathing depth. Pan

Huashan systematically studied the structure of Ba Duan Jin's movements and found that the movements such as 'two hands supporting the heavens and three focal points' can increase the volume of the thoracic cage, increase the amount of gas inhaled and increase the lung capacity for long-term exercises, which significantly improves the endurance level of the ventilator. Feng Yizheng et al. research showed that after 12 weeks of more standard Ba Duan Jin exercises, it significantly improved the lung function of elderly patients with stable COPD, significantly increased PaO₂, reduced PaCO₂ and effectively increased patients' 6MWD; after 24 weeks after practicing Baduanjin, one can achieve better treatment results, especially in improving various lung function indicators and increasing 6MWD. The average HR of the subjects was 97.5 ± 10.34 l/min, which was slightly lower than the optimal load area for aerobic metabolism. In the ninth set of broadcast gymnastics, the average HR of the subjects was 126.13 ± 15.481 /min, which is within the optimal load zone for aerobic metabolism. From the average heart rate, we can say that there are no negative oxygen debts in the two sports programmes of Baduanjin and the ninth set of radio gymnastics, which meet the HR training standards for national fitness. Some studies have pointed out that long-term aerobic exercise can thicken the myocardial wall of the subject, enhance the subject's heart valve elasticity, increase cardiac output, reduce myocardial oxygen consumption and improve the blood pumping function of the heart. The increase in oxygen pulse indicates that in Baduanjin and the ninth set of broadcast gymnastics, the body's oxygen consumption increases, which not only needs to be accomplished by increasing blood flow, but also the improvement of haemoglobins ability to bind oxygen. Figure 4 shows Energy consumption path of sports [6].

Fig. 4 Energy Consumption before and after Baduanjin and Ninth Broadcast Gymnastics

4.2 Sexual characteristics of energy expenditure and substrate metabolism

The data of this study show that there is no significant difference in EE/kg between men and women, whether at rest or during exercise, but there are significant differences in fat energy supply, protein, fat energy supply ratio, EE and RER, which is similar to Knechtle et al. Human research results are always consistent. In the same exercise, the total energy consumption of men is higher than that of women, while the proportion of fat energy supply is significantly lower than that of women, indicating that resting energy consumption and substrate metabolism are not only affected by receptor weight, but may also be affected by hormone levels, influence of muscle content and substrate differences [7]. Studies have shown that differences in substrate metabolism between men and women are related to oestrogen, which promotes lipid metabolism by increasing lipopro-

teinase activity. Studies by Tracy et al. found that during exercise, male adrenaline and norepinephrine levels were significantly higher than those of females, and females were more sensitive to catecholamine hormones promoting fat energy breakdown. During moderate-intensity exercise, women release more triglycerides and fatty acids than men, and an increase in the supply of plasma fatty acids leads to women's fatty acid intake and oxidative capacity being higher than men. Wang Li's research shows that whether REE is affected by gender is inconclusive. Some studies have found that males have higher REEs than females.

The effect of this differential receptor weight or fat free mass (FFM) However, Yang Ming et al. believed that even if the body weight is adjusted, there is still a difference in REE between men and women. Tang Qiang and others used indirect calorimetry to measure the energy consumption of several common forms of upper limb exercise, and the results showed that resting oxygen consumption was higher in men than in women. By studying the energy expenditure during climbing stairs of different weight groups [8], Yuan Lin et al. found that in quiet state, the energy consumption per unit weight of men is greater than that of women, which may be caused by gender differences in muscle content, hormone levels and metabolic status. Liang Jie et al used indirect calorimetry to measure the basal metabolism of 61 healthy college students of a university in Guangdong. The results showed that the basal metabolic rate and total daily consumption of male college students were higher than those of female college students.

4.3 Age characteristics of energy expenditure and substrate metabolism

In this experiment, although there was no significant difference in resting energy consumption between subjects aged 20–39 years and subjects aged 40–59 years, there were very significant differences in sugar energy supply and EE/kg [9]. It shows that REE decreases with age, which is directly related to the decline of basal metabolic rate of the human body with age. When the subjects in the Baduanjin group did exercise, there were significant differences between the 20–39-year-old and 40–59-year-old subjects in sugar energy supply, fat energy supply ratio and RER; in the radio gymnastics group, for 40–59 years, the fat energy supply is significantly higher in the age group than in the 20–39 age group. There are also very significant differences in protein, EE and EE/kg and no significant difference in sugar energy supply, fat energy supply ratio and RER, indicating that energy consumption is affected by age. The EE/kg of subjects aged 40–59 years was below 20–39 years in quiet state, while it was higher than 20–39 years in Baduanjin exercise, and significantly higher than 20–39 years in ninth set of broadcast gymnastics [10]. This shows that although the EE/kg of subjects in both age groups increased with the increase in exercise intensity, the rate of EE/kg increase in subjects aged 40–59 years was higher than that in 20–39 years. This is consistent with the results of previous studies. Tang Qiang et al. found that the resting energy consumption of subjects aged 20–39 years was higher than that of 40–59 years, but the relative energy consumption increase during the swing arm exercise was less than 40–50 years old, because the younger group of sports is more efficient and saves energy during exercise. The proportion of fat energy supply in subjects aged 20–39 years was significantly higher than that in subjects aged 40–59 years in all three states, but there was no significant difference. This phenomenon may be due to the fact that with age, the body's cardiopulmonary function and muscle oxidative energy supply capacity gradually decline, manifested in the same exercise intensity (%VO₂max), the fat energy supply capacity decreases, and at the same time lead to the same in the low-medium intensity range. When exercising at absolute intensity, the decline in neuromuscular coordination results in lower muscle work efficiency and increased total body energy expenditure. Indirect calorimetry was used to study the walking energy expenditure characteristics of healthy people of different ages. Wang Li et al. found that the REE of women aged 41–50 was significantly lower than that of women and men aged 21–30. This study found that the resting energy expenditure of subjects aged 40–59 years was higher than that of subjects aged 20–39 years, and the REE of female subjects in each group was lower than that of male subjects. Yang Ming et al. conducted a study on 156 healthy people and found that REE/kg in middle-aged and elderly people gradually decreases with age, and this energy consumption does not affect the amount of receptor lipid. Figure 5 shows schematic diagram of energy consumption [11].

Fig. 5 Schematic diagram of energy consumption

4.4 Characteristics of energy consumption and metabolic substrate of baduanjin and ninth broadcast gymnastics

In Baduanjin and the ninth set of radio gymnastic exercises, the subjects RERs were significantly different when they were quieter, which indicates that these two exercises increased the subject's energy expenditure. In a quiet state, the body is mainly powered by sugar. In Baduanjin and the ninth set of radio gymnastics, the total energy and energy consumption of the body increases, and thus sugar and fat energy increases. The increase in Fat energy supply is related to the fact that Baduanjin and the ninth set of radio gymnastics belong to low and medium intensity sports [11].

Romijn et al. pointed out that sugar oxidation increases with increasing exercise intensity and fat oxidation reaches the highest at 65%VO₂max. There was a significant difference in the sugar energy supply of the subjects in the Baduanjin group and the ninth set of radio gymnastics groups. Considering the subjects' fat energy, the data of this study show that there is no significant difference in EE/kg between men and women, whether at rest or during exercise, but there are significant differences in fat energy supply, protein, fat energy supply ratio, EE and RER, protein energy, fat function ratio, EE, and EE/kg were significantly higher in the Baduanjin exercise. In the ninth set of broadcast gymnastics, it shows that the exercise intensity of the ninth set of broadcast gymnastics is higher than that of Baduanjin. Although the subjects' energy consumption and substrate metabolism are significantly different in these two types of exercise, both types of exercise can increase energy consumption and promote fat metabolism to achieve fitness. Miao Fusheng divided 50 elderly patients with hyperlipidaemia into an experimental group and a control group. The experimental group practiced Health Qigong Baduanjin for 18 months, and compared total cholesterol (TC), apolipoprotein A1 (ApoA1) and lipid-laden before and after the experiment, protein B (ApoB) content, high-density lipoprotein cholesterol (HDL-C), triglyceride (TG) and low-density lipoprotein cholesterol (XDL-C). Health Qigong Baduanjin exercise can improve lipid metabolism and reduce the patient's blood lipid level, which is very beneficial for the prevention and treatment of hyperlipidaemia. Baduanjin and the ninth set of radio gymnastics are easy to master, suitable for all ages, and have few requirements for equipment and venues, which can contribute to the national fitness.

4.5 Establishment of baduanjin and ninth set of multiple linear regression equations for broadcast gymnastics

Tests were performed on the regression models of the heart rate, weight and energy expenditure of the subjects during the resting state, Baduanjin and the ninth set of broadcast gymnastics. The results showed that the P values of the three models were less than 0.01, proving the regression model equations of subjects under these three conditions can be used to express the correlation between their heart rate, weight and energy expenditure. The heart rate and weight were used as independent variables to calculate the energy consumption equations at rest, Baduanjin and the ninth set of broadcast gymnastic exercises. The slope and intercept of the three equations were significantly different ($P < 0.01$) where a is the subject's weight in kg, b is the quiet heart rate in bpm and c is the heart rate during exercise in bpm. The independent variable coefficients and constant terms of the regression equation are of significant significance ($P < 0.01$). The regression equations are:

Resting energy consumption per unit time = $38.015 + 17.68a + 9.75b$.

Energy consumption of Ba Duan Jin per unit time = $1487.116 + 67.079a + 14.328c$.

Energy consumption of the ninth set of broadcast gymnastics per unit time = $3312.772 + 127.321a + 22.713c$.

The complex correlation coefficients of the equation reach the values 0.633, 0.661 and 0.743, respectively and three equations above are obtained.

Net energy consumption of Ba Duan Jin per unit time = energy consumption of Ba Duan Jin per unit time – resting energy consumption per unit time = $1449.101 + 49.399a - 9.75b + 14.328c$.

Net Energy Consumption of Ninth Set of Broadcast Gymnastics per Unit Time = Energy Consumption of Broadcast Gymnastics per Unit Time – Resting Energy Consumption per Unit Time = $-3350.787 + 109.641a - 9.75b + 22.713c$.

This equation can quantify energy consumption, more accurately guide national fitness and achieve optimal training results while ensuring safety.

5 Conclusion

Baduanjin belongs to low-intensity exercise and the ninth set of broadcast gymnastics belongs to medium-intensity exercise. Comparing the Baduanjin and the ninth set of radio gymnastics at the state of exercise, the ninth set of broadcast gymnastics body energy consumption and fat energy supply ratio were significantly higher than that of Baduanjin exercise. Net energy consumption of Ba Duan Jin per unit time = $1449.101 + 49.399a - 9.75b + 14.328c$; Net energy consumption of the ninth set of broadcast gymnastics per unit time = $-3350.787 + 109.641a - 9.75b + 22.713c$ (a represents the weight of the subject, unit: Kg; b for quiet heart rate, unit: bpm; c , heart rate during exercise, unit: bpm).

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