Determining Energy Expenditure from Heart Rate Monitoring during Training Sessions at Bulgarian Wrestlers

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Abstract: *Aim of the study was to determine physical activity's part of daily energy expenditure by heart rate monitoring and using data to control athletes' nutritional intake. Group of 10 male and 4 female wrestlers (age = 21 ± 1.8) at national level, who train 15 hours per week served as subjects in this investigation. The 72-hour HR recording was performed with a TEMEO cardiotelemetric system (made in Bulgaria). The energy expenditure during physical activity is determined by Method 1 of Hiilloskorpi et al. (2003). The determined daily energy expenditure is compared to the theoretically calculated. The deference is less than 100 kcal, but if subjects change the intensity, volume or duration of the workouts or increase their number, the difference will be much more evident.*

Keywords: *Energy expenditure, Heart rate monitoring, Physical activity.*

Introduction

The athletes' diet is in relation with their Daily Energy Expenditure (DEE). General components of DEE are Basal Metabolic Rate (BMR) and Energy Expenditure by physical activity (EE). The second component – EE depends on the number, volume and intensity of training sessions. Pattern of EE of any sport is important to the coaches and athletes to apply proper nutritional strategy and well organized training plan.

There are many methods of EE measuring like: direct calorimetry, respiratory indirect calorimetry, Sensor of Heat and Movement (SHM) [11]. The disadvantages of these methods are the expensive technique, the need of specialists, the accuracy of the measurement (for example SHM) or are not applicable to sports like wrestling, judo or boxing [11].

A linear relationship between Heart Rate (HR) and oxygen consumption during physical activity has been established [9]. Most equations for EE assessing by HR monitoring during physical activity are based on this linear dependence [8, 13]. In two studies, energy expenditure during physical activity was measured by heart rate monitoring, but instead of individual calibration, the authors use predictive equations generated by large contingents [6, 12]. Research of Hiilloskorpi et al. [6] shown that factors such as age, gender, and weight have a significant impact in determining energy consumption while the type of load (cycling vs.

running) has no significant impact on the model. Hiilloskorpi et al. [7] analyse three equation models and suggest two equations for each model – for low and high activity. Usually the boundary between the two activities is in the range of 80 to 100 beats per minute [14].

Materials and methods

Subjects

14 wrestlers (10 male and 4 female) at national level aged between 18 and 25 years (on average 21 ± 1.8 years old) served as subjects in this investigation. The mean period of sports practice was 6.2 (± 1.7 SD) years. All subjects participated in 15 hours of training per week. None of them was taking any drugs or medications.

Study design

The aim of the study was to determine physical activity's part of daily energy expenditure by heart rate monitoring during training sessions and using the data to control the athletes' nutritional intake and body mass. The duration of the study was 72 hours (three days). This period included 5 different types of training, applied to the weekly training process. A three-day heart rate recording was performed during the study. HR data during training sessions was used to assess the energy consumption of physical activity. The received data were compared with the theoretically calculated values.

Anthropometric measurements

The weight and height of each subject was measured. Body mass was recorded to the nearest 0.05 kg using a portable digital scale with each subject wearing light clothing and no footwear. Height was measured to the nearest 0.5 cm.

Body composition (Body Fat Percentage (%BF) and Fat Free Mass (FFM)) was determined by bioelectrical impedance analyser Tanita BC418. The measurements were in accordance with the operation protocol.

Heart rate monitoring

The heart rate monitoring was registered by the TEMEO system (Security Solutions Institute, Bulgaria, patent 1375/2010) [10]. The system recorded the R-R intervals with a precision of 1 msec. The received information was being transmitted every 5 minutes via GSM communication to a research server (Fig. 1). The minimum (HRmin), mean (HRavg), and maximum (HRmax) heart rates were calculated automatically. HRavg was the average heart rate over the 5-minute period.

Daily calorie needs

BMR were theoretically determined using Harris and Benedict's Eqs. (1) and (2) [5]. Daily Calorie Needs (DCN) is BMR multiplied by the appropriate activity factor (Table 1).

For men:

$$BMR = 66.5 + (13.75 \times \textit{weight in kg}) + (5.003 \times \textit{height in cm}) - (6.755 \times \textit{age in years}) \quad (1)$$

For women:

$$BMR = 655.1 + (9.563 \times \textit{weight in kg}) + (1.850 \times \textit{height in cm}) - (4.676 \times \textit{age in years}) \quad (2)$$

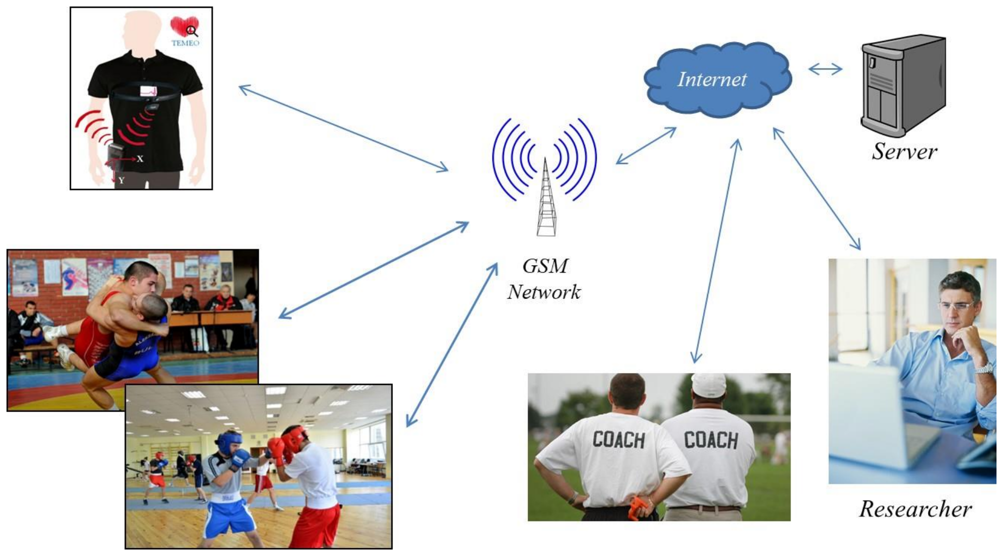

Fig. 1 Mobile cardiac telemetry system TEMEO

Table 1. Physical activity factor

1. If you are sedentary (little or no exercise): *DCN* = *BMR* × 1.2
2. If you are lightly active (light exercise/sports 1-3 days/week): *DCN* = *BMR* × 1.375
3. If you are moderately active (exercise/sports 3-5 days/week): *DCN* = *BMR* × 1.55
4. If you are very active (hard exercise/sports 6-7 days/week): *DCN* = *BMR* × 1.725
5. If you are extra active (very hard exercise/sports or 2 × training): *DCN* = *BMR* × 1.9

Energy expenditure during physical activity

For determination of EE during physical activity from HR Hiilloskorpi et al. [7] Eqs. (3)-(6) were used.

For men:

low activity: $EE = 4.56 - 0.0265 \times (HR) - 0.1506 \times (weight) + 0.00189 \times (HR) \times (weight)$ (3)

high activity: $EE = 3.56 - 0.0138 \times (HR) - 0.1358 \times (weight) + 0.00189 \times (HR) \times (weight)$ (4)

For women:

low activity: $EE = -4.70 + 0.0449 \times (HR) - 0.0019 \times (weight) + 0.00052 \times (HR) \times (weight)$ (5)

high activity: $EE = -5.92 + 0.0577 \times (HR) - 0.0167 \times (weight) + 0.00052 \times (HR) \times (weight)$ (6)

The boundary between the two activities is in the range of 80 to 100 beats per minute [14].

Daily Energy Expenditure (DEE):

$$DEE = BMR \times 1.2 + EE \quad (7)$$

Statistical analysis

Anthropometric, HR and calorie data are presented as an average and standard deviation.

Results and discussion

Anthropometric indicators are presented in Table 2. BMI in males is above normal (*BMI* = 20-25 kg/m^2), which is typical for strength athletes and is due to the higher amount of muscle mass. %BF is relatively high (especially for women) for this type of sport. For men 7% to 10% and for women between 12% and 15% is considered for ideal %BF [2-4, 15].

Table 2. Anthropometric data of the participants (± SD)

	Men (*n* = 10)	**Women (*n* = 4)**
Age, (years)	21 ± 1.8	19 ± 0.8
Height, (cm)	174 ± 7.8	158 ± 2.8
Weight, (kg)	79.5 ± 10.2	58.7 ± 2.8
BMI, (kg/m^2)	26.5 ± 1.9	23.4 ± 0.9
%BF	11.9 ± 2.6	21.0 ± 1.8
FFM, (kg)	67.8 ± 7.7	44.0 ± 2.9

Fig. 2 and Fig. 3 show three-day HR recordings some of the participants. The graphs show how much intensity and how long each person performs different types of training.

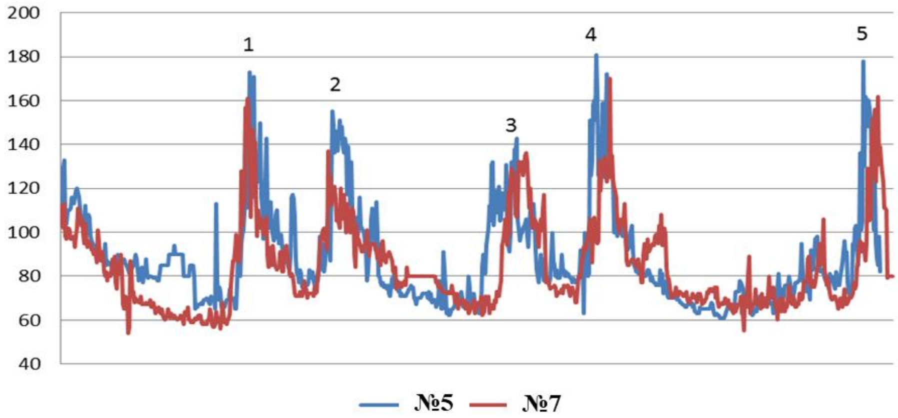

Fig. 2 Three-day HR records of participants № 5 and № 7 (men):
1 – HR during training with elastic ropes; 2 – General Physical Preparation (GPP);
3 – weightlifting; 4 – technical training; 5 – run.

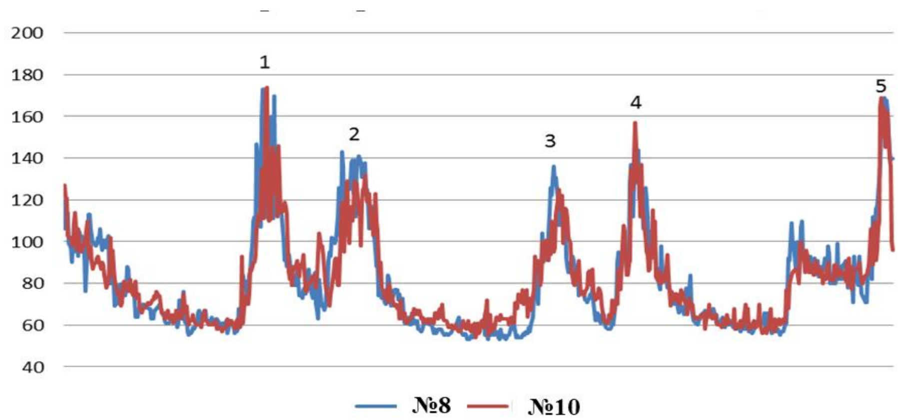

Fig. 3 Three-day HR records of participants № 8 and № 10 (women):
1 – HR during training with elastic ropes; 2 – General Physical Preparation (GPP);
3 – run; 4 – weightlifting; 5 – technical training.

Averaged values of EE at the different physical activities, set in the weekly training plan of the surveyed competitors are presented in Table 3. Between men and women, the difference is between 1 and 2 kcal/kg/h for different types of workouts. The highest EE was recorded during the technical training (8.2 kcal/kg/h) for the men and during the training with elastic ropes for the women (6.7 kcal/kg/h).

Table 3. Mean values of EE (kcal/kg/h) at different types of training

	Training with elastic ropes	GPP	Weightlifting	Technical training	Run
Men	7.8 ± 0.4	7.5 ± 1.4	7.3 ± 0.3	8.2 ± 1.5	6.7 ± 1.5
Women	6.7 ± 0.9	6.4 ± 1.1	5.2 ± 1.0	6.3 ± 1.9	5.4 ± 0.2

Individual EE estimates for different types of training in some of the surveyed competitors are presented in Tables 4 and 5. The lower energy expenditure for women is due to a lower percentage of muscle mass and lower body weight. Mean values of theoretically calculated DCN and DEE (Table 6) based on HR during physical activity are less than 100 kcal/24h (less than 3%), both in men and women.

Table 4. EE in periods of physical activities of participants № 5 and № 7 (men)

	Training with elastic ropes	GPP	Weightlifting	Technical training	Run
№ 5	8 kcal/kg/h	8.4 kcal/kg/h	7 kcal/kg/h	9.4 kcal/kg/h	6.8 kcal/kg/h
	568 kcal/h	596 kcal/h	497 kcal/h	667 kcal/h	483 kcal/h
№ 7	7.4kcal/kg/h	6.5 kcal/kg/h	7.3 kcal/kg/h	7.4 kcal/kg/h	6.8 kcal/kg/h
	512 kcal/h	450 kcal/h	505 kcal/h	512 kcal/h	471 kcal/h

Table 5. EE in periods of physical activities of participants № 8 and № 10 (women)

	Training with elastic ropes	GPP	Weightlifting	Technical training	Run
№ 8	7.2 kcal/kg/h	7.1 kcal/kg/h	5.8 kcal/kg/h	7.4 kcal/kg/h	5.3 kcal/kg/h
	400 kcal/h	395 kcal/h	323 kcal/h	411 kcal/h	295 kcal/h
№ 10	6.0 kcal/kg/h	5.5 kcal/kg/h	4.4 kcal/kg/h	4.8 kcal/kg/h	5.5 kcal/kg/h
	356 kcal/h	327 kcal/h	261 kcal/h	285 kcal/h	327 kcal/h

Table 6. DCN and DEE in kcal/24h

	Men (n = 10)	Women (n = 4)
DCN, (kcal/24h)	3453 ± 272	2651 ± 79
DEE, (kcal/24h)	3364 ± 223	2572 ± 112

DEE values are for a weekly training plan including 15 hours of physical activity (10 workouts at 1 h and 30 min). Except data from Compendium of Physical Activities [1], there was no other information about energy consumption for wrestling in the literature. Ainsworth et al. [1] reported that for a 5-minute wrestling match energy expenditure is 6 METs (6 kcal/kg/hr), but did not specify the method by which it was calculated.

In technical training, which includes combat, our EE calculations based on HR are 8.2 kcal/kg/h for men and 6.3 kcal/kg/h for women, ranging from 5 to 9.5 kcal/kg/h.

DEE calculated as the sum of BMR multiplied by an activity factor 1.2 (for non-training) and EE from the physical activity during a workout based on HR record, has a difference of less than 100 kcal/24h compared to DCN – calculated as BMR multiplied by an activity factor of 1.9 (for individuals who train 8 or more times a week). In our case, athletes train 15 hours per week (10 times at 1.5 hours). If they change, intensity, volume or duration of training or increase their number, the difference will be much more evident.

Conclusion

EE assessment by HR during physical activity is an easily accessible method that allows an individual approach in DEE determining and energy intake at each stage of the training process in wrestling.

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