Sports Science

Estimated energy expenditure and training intensity in young female artistic gymnasts

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Abstract - Aim: This study determined the energy expenditure and effort intensity of athletes during women's artistic gymnastics training sessions. **Methods:** Ten gymnasts (age 10.9 ± 1.7 years) performed a test to estimate the maximum rate of oxygen uptake (VO_{2max}), during which the maximum heart rate (HR_{max}) was also obtained. The heart rate (HR) of these gymnasts was recorded during five training sessions and then used to estimate the exercise intensity and energy expenditure. **Results:** Mean duration of training sessions was 4.08 ± 0.42 h, with mean HR corresponding to 137 ± 8 bpm or $69.0 \pm 3.5\%$ of HR_{max}. Gymnasts spent less training time at 90-100% HR_{max} compared to the other HR ranges ($p < 0.05$). Time spent at 60-70% and 70-80% was higher compared to 80-90% HR_{max} ($p = 0.012$ and $p = 0.001$, respectively). The training impulse was 239.2 ± 35.4 AU. Estimated energy expenditure was 768.3 ± 168.5 kcal, metabolic rate was 3.1 ± 0.6 kcal/min, and the metabolic equivalent of task (MET) corresponded to 6.1 ± 0.6. **Conclusion:** Young gymnasts performed prolonged and moderate-intensity training sessions that generated high energetic demands. This information is beneficial to gymnasts since the coaching team can use the data to control the training load and prescribe a proper diet.

Keywords: energy expenditure, effort intensity, TRIMP, training sessions, women's artistic gymnastics.

Introduction

Women's artistic gymnastics (WAG) is an individual sport where athletes perform routines on four apparatuses: vault, uneven bars, balance beam, and floor[1]. Vault requires explosive force generation, uneven bars demand upper body strength for release and catch movements, beam requires balance and artistry, and floor demands the generation of leg impulse for tumbling alongside artistry for linking movements[2]. Therefore, female gymnasts must develop sport-specific physical and motor abilities and technical skills[3]. Also, they usually present specific anthropometric characteristics, such as reduced body mass and height as well as high levels of muscular strength, power, and flexibility[4,5]. Altogether, these characteristics favor performance in specific skills of artistic gymnastics[5,6]. Although artistic gymnastics is one of the most popular Olympic sports, there are few studies about its physiological demands[3], particularly few studies including young (i.e., child and adolescent) female gymnasts[1,5,7].

Training sessions in WAG usually consist of a warm-up and routine training on the apparatuses, alongside strength-building and stretching exercises[7]. Depending on the time of the season, WAG sessions often also consist of special element/skill training. A gymnast focuses on a technicality and commonly completes many repetitions and combinations of skills during prolonged training sessions[2,4]. For example, Brazilian gymnasts train 2 to 6 times per week, on average 12 to 24 h per week, 1.0 to 6.5 h per training session, depending on the athlete's competition level[8]. Due to the specificity of each apparatus and the long training routines, quantifying and monitoring training load are essential for coaches to help gymnasts achieve optimal performance. Further, ensuring a proper load distribution is required during periodization, aiming to reach the best performance in the most important competitions[8,9].

Valuable data that enable better control of training loads can be obtained through monitoring the heart rate (HR). For example, Marina and Rodriguez[10] examined the

HR of gymnasts in competition routines, though this study lacks investigation about training sessions. Among these important data, the energy expenditure of the gymnasts should be highlighted. A previous study showed that HR is valid to estimate the rate of oxygen uptake (VO_2) during intermittent aerobic exercise[11]. These authors reported 71% of the HR variance was explained by VO_2 variations when these measurements were obtained during a soccer match and using a portable gas analyzer[11]. Thus, the HR-VO_2 relationship could be applied during prolonged gymnastics training sessions, where the intermittent aerobic nature is also evident. Further, data on the energy cost of WAG training sessions are necessary to update the Compendium of Physical Activities[12], a resource for classifying the energy cost of human physical activities.

Thus, the knowledge about the intensity of effort and energy expenditure during WAG training sessions is crucial for prescribing adequate training loads and respective nutritional intake, thereby ensuring good health status in young female gymnasts. The excessive preoccupation with maintaining a reduced body mass can lead to a weakened nutritional status that, associated with high-intensity training, can delay the age at menarche[13]. Moreover, the HR response can provide coaches with a guideline for adequate WAG training and a more integrated view of the training sessions' monitoring process. Therefore, this study aimed to determine the exercise intensity and estimate the energy expenditure of young Brazilian gymnasts during WAG training sessions.

Methods

Participants

A total of 10 female gymnasts (age 10.9 ± 1.7 years, body mass 31.2 ± 6.8 kg, height 134.6 ± 10.9 cm, body fat $12.5 \pm 2.0\%$) took part in this study. The gymnasts were involved in systematic training of WAG for at least 5 years before this study and had already participated in national competitions. This group of athletes was aimed at initial elite training. The gymnasts trained, on average, 20 h per week (i.e., five sessions lasting 4 h each during the weekdays).

This study was approved by the Research Ethics Committee of the local university (approval reference number: 32008814.4.0000.5149) and was conducted under the policies established by the Brazilian National Health Council (Resolution 416/12) for research with humans. A legal representative of each child/adolescent gymnast signed a written consent form confirming he/she was aware of the objectives and procedures that would be performed. The gymnasts signed a written informed assent form, written in the appropriate language according to their age, and were informed they could leave the study at any time, without the need to justify their decision to researchers.

Experimental design

Initially, anthropometric measurements were obtained, and the gymnasts performed the multistage 20-m shuttle run test to estimate their maximum rate of oxygen consumption (VO_{2max})[14], during which the maximum heart rate (HR_{max}) was also recorded (Table 1). Then, the HR measurements were obtained in five training sessions per athlete (Polar Electro Oy®, Polar Team System, Finland). Data collection occurred between February and May, in the preparatory phase for the national competition (August), the seasons' main competition for these athletes. Most training sessions consisted of three main parts: general and specific warm-up, alongside basic acrobatic movements; (2) routine training on the apparatuses; (3) strength and conditioning, with strength-building and stretching exercises. Some sessions also included ballet exercises.

Body composition evaluation

The percent body fat was estimated according to the equation proposed by Slaughter et al.[15], with measures obtained at two sites (i.e., subscapular and triceps) through a skinfold caliper (Lange, Cambridge Scientific Industries, Watertown, MA, USA).

Assessment of the maximum rate of oxygen uptake

During the multistage 20-m shuttle run test[14], the gymnasts used a chest strap to monitor their HR and ran as long as possible over a distance of 20 m demarcated by cones at the speed indicated by a recorder. A beep warned when gymnasts should be at one end or another extremity of the 20-m track. The test was interrupted when the ath-

Table 1 - Anthropometric and physiological characteristics of the athletes.

	Age (years)	Weight (kg)	Height (cm)	Body fat (%)	$\Sigma_{skinfold}$ (mm)	VO_{2max} (mL.kg^{-1}.min^{-1})	HR_{max} (bpm)
Mean	10.9	31.2	134.6	12.5	12.9	40.0	199
SD	1.7	6.8	10.9	2.0	2.0	3.5	8
CV (%)	15.9	21.7	8.1	15.9	15.3	8.7	4
Minimum	9.0	24.7	120.5	8.4	9.0	35.0	185
Maximum	14.0	47.1	156.5	15.5	16.0	44.9	209

CV = coefficient of variation, HR_{max} = maximum heart rate, SD = standard deviation, VO_{2max} = maximum rate of oxygen uptake.

lete could not reach the cone within the predetermined time for two consecutive beeps or when the athlete herself voluntarily decided to stop the exercise[14]. The HR was recorded by the evaluator every min during the test and when each athlete has fatigued. The HR_{max} of each gymnast was the highest HR value recorded during the test.

Training heart rate measure

The HR was continuously recorded throughout five training sessions per athlete (Polar Electro Oy®, Polar Team System, Finland). The use of this equipment allows the HR recording while training without using a wrist monitor, which ensures the completion of all movements without restrictions and avoids risks to the physical integrity of gymnasts and coaches. Subsequently, the data stored were transferred to a computer through an interface, cataloged, and analyzed using the Polar Precision Performance SW (version 3.0) software.

All training sessions were conducted indoors, in the afternoon, and the environmental conditions were monitored using a thermo-hygrometer (Alla France, Chemillé-Melay, France). The wet-bulb globe temperature (WBGT) was calculated using the wet- and dry-bulb temperatures according to the following equation: WBGT (°C) = 0.7 x wet-bulb temperature + 0.3 x dry-bulb temperature[16].

Determination of the exercise intensity during training sessions

The exercise intensity was estimated from the average of HR measurements obtained during the entire training session. The intervals between exercises, during which the gymnasts placed ice on body regions where they felt pain or engaged in atypical activities, such as physiotherapy sessions and break for snacks, were not excluded from the analysis to maximize data's ecological validity. The training sessions usually ended with a conversation between the coach and gymnasts. The training duration corresponds to the time elapsed between the beginning and end of the session, including the final coach feedback.

The exercise intensity (i.e., percentage of the HR_{max}) was calculated by dividing the average HR value obtained during the training session by the HR_{max} attained during the VO_{2max} test (20-m shuttle run test). The exercise intensity expressed as the percentage of the VO_{2max} was obtained from the direct relationship between the percentages of the HR_{max} and VO_{2max}[17-19].

Energy expenditure (kcal) and metabolic rate ($kcal.min^{-1}$) were estimated from the oxygen uptake values. The metabolic equivalent of task (MET) was obtained by dividing the VO_2 values in $mLO_2.kg^{-1}.min^{-1}$ by 3.5 $mLO_2.kg^{-1}.min^{-1}$. The total energy expenditure of each athlete was then calculated by multiplying the body mass (kg) by the exercise intensity (expressed in multiples of MET; each MET corresponds to 1 $kcal.kg^{-1}.h^{-1}$) and by the training session duration (h)[17]. Because energy

supply depends predominantly on the aerobic pathway in physical exercises lasting more than two minutes[20], the HR-VO_2 relationship is a valid method to estimate energy expenditure during prolonged training sessions and intermittent activities[11,18,19,21,22].

Further, to determine the internal training load, quantified by the training impulse (TRIMP), the accumulated training duration in five HR zones relative to HR_{max} was multiplied by a coefficient for each zone, according to Edwards[23].

$$\text{TRIMP (AU)} = (\text{Dz}\,1 \times 1) + (\text{Dz}\,2 \times 2) +$$

$$(\text{Dz}\,3 \times 3) + (\text{Dz}\,4 \times 4) + (\text{Dz}\,5 \times 5)$$

where Dz i is the duration in zone i. zone 1 = 50-60% HR_{max}; zone 2 = 60-70% HR_{max}; zone 3 = 70-80% HR_{max}; zone 4 = 80-90% HR_{max}; zone 5 = 90-100% HR_{max}.

Statistical analyses

Shapiro-Wilk tests were used to verify the data normality. Mauchly's test was consulted, and the Greenhouse-Geisser correction was applied if sphericity was violated. All the data regarding environmental conditions, athlete's anthropometric and physiological characteristics, training intensity, energy expenditure, and TRIMP are presented as mean ± standard deviation (SD). The coefficient of variation (CV) and the maximum and minimum values of the parameters listed above were also presented to ensure a complete descriptive analysis of the data collected (except the environmental conditions). The percentage of total training time in different HR zones (0-60, 60-70, 70-80, 80-90, and 90-100 % HR_{max}) was outlined for each athlete. One-way repeated-measures analysis of variance (ANOVA) and Sidak *post hoc* test were used to compare the percentage of total training time at the different HR zones. The effect size was reported based on partial eta squared (η^2) from the ANOVA. Data analyses were conducted in Statistical Package for the Social Sciences (SPSS version18.0, Chicago, IL, USA) and Graphpad® software (Prism5.0, San Diego, CA, USA).

Results

The training sessions were performed indoors with average WBGT and relative humidity of 22.9 ± 1.9 °C and 68.1 ± 10.5%, respectively. The mean training session duration was 4.08 ± 0.42 h.

Mean HR during the training sessions was 137 ± 8 bpm, which corresponded to 69.0 ± 3.5% of HR_{max}. To better understand the intensity of the gymnastic training sessions, the HR responses were separated into five ranges, namely 0-60, 60-70, 70-80, 80-90, and 90-100% of HR_{max}. The time spent at each of these ranges (i.e., the percentage of session duration) was determined for each

athlete. Great variability in the HR responses among gymnasts was observed; for example, athlete #6 spent 7.7% of the training sessions at an HR range above 90-100% of her HR_{max}, whereas athlete #1 spent only 0.6% of the training sessions at this intensity (Figure 1). Despite the great variability observed, all 10 gymnasts spent more than 60% of training duration in intensities corresponding to less than 80% of HR_{max}, and more than 90% of training duration in intensities lower than 90% of HR_{max}. Analyzing the mean values, the gymnasts spent the most and the least of the training session's duration (30.4% and 3.7%) in intensities corresponding to 60-70% and 90-100% of HR_{max}, respectively (Figure 1). A significant effect was observed comparing the percentage of total training time at different ranges [$F_{(2,13)} = 23.081$, $p = 0.001$, $\eta^2 = 0.719$]. Time spent at 90-100% HR_{max} was significantly lower compared to the other four ranges ($p < 0.05$). Furthermore, time spent at 60-70% and 70-80% was significantly higher compared to 80-90% HR_{max} ($p = 0.012$ and $p = 0.001$, respectively) (Figure 2).

Energy expenditure was estimated from HR data (Table 2). The gymnasts had average energy expenditure and metabolic rate that corresponded to 768.3 $\pm$ 168.5 kcal and 3.1 $\pm$ 0.6 kcal.min^{-1}, respectively; thus, the gymnastics training sessions presented a metabolic rate that was 6.1 $\pm$ 0.6 times the resting metabolic rate. Finally, the average TRIMP value corresponded to 239.2 $\pm$ 35.4 AU. For a complete description of the WAG training sessions, individual data obtained for each athlete in the five training sessions are shown in Table 3.
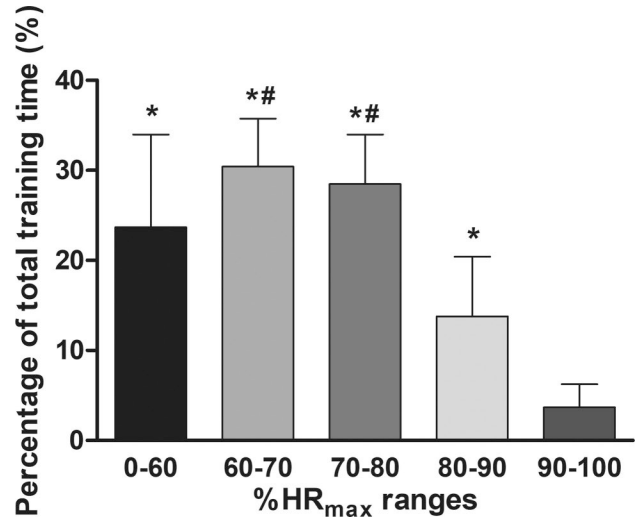

Figure 2 - Average time spent at five different exercise intensities, determined by the maximum heart rate percentage, during gymnastic training sessions. HR_{max} = maximum heart rate, *means significantly different from 90-100% HR_{max}, #means significantly different from 80-90% HR_{max}, $p < 0.05$, n = 10.

Discussion

This study determined the intensity of effort and energy expenditure during artistic gymnastic training sessions. The gymnasts presented a mean absolute HR of 137 $\pm$ 8 bpm, while relative values corresponded to 69.0 $\pm$ 3.5% of HR_{max}. Furthermore, the internal load was also quantified with TRIMP values of 239.2 $\pm$ 35.4 AU.
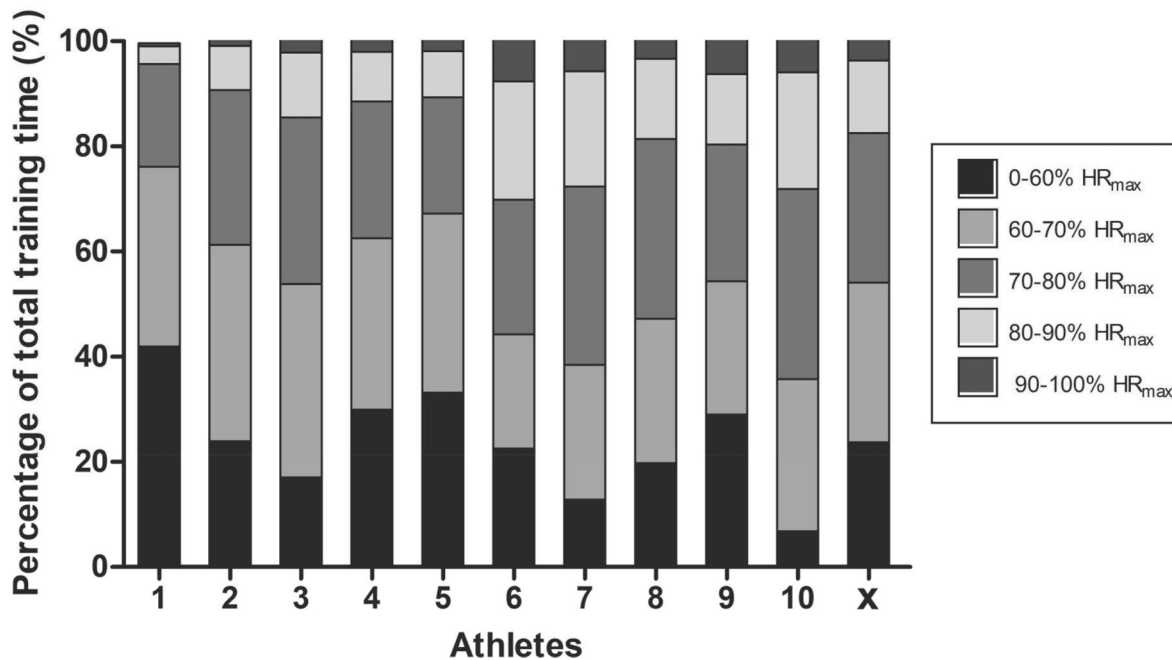

Figure 1 - Time spent at five different exercise intensities, determined by the maximum heart rate percentage, during gymnastic training sessions. Each bar represents one athlete, and the "X" bar represents the mean group response. HR_{max} = maximum heart rate.

Table 2 - Characterization of artistic gymnastic training sessions.

	Duration (h)	HR (bpm)	% HR_{max}	EE (kcal)	Metabolic rate (kcal/min)	MET	TRIMP (AU)
Mean	4.1	137	69.0	768.3	3.1	6.1	239.2
SD	0.4	8	3.5	168.5	0.6	0.6	35.4
CV (%)	10.3	6	5.1	21.9	20.7	9.3	15.2
Minimum	2.7	121	62.8	589.2	2.3	5.3	176.0
Maximum	4.9	149	74.2	1043.8	4.4	7.0	292.3

CV = coefficient of variation, EE = energy expenditure, HR = heart rate, HR_{max} = maximum heart rate, MET = metabolic equivalent of task, SD = standard deviation, TRIMP = training impulse.

Gymnasts' energy expenditure was 768.3 ± 168.5 kcal, with a metabolic rate of 3.1 ± 0.6 kcal.min^{-1} or 6.1 ± 0.6 times resting values. Thus, the physiological demand characterization of WAG training sessions was obtained.

In the present study, HR was recorded during 5 training sessions per athlete. No other WAG study reported this variable during training sessions, making comparisons difficult. However, some studies have reported the physiological demands during simulated gymnastic competitive routines[1,10]. These studies showed the gymnasts reached their highest HR values (183 - 199 bpm) in the floor and uneven bars exercises, while the vault is the apparatus with the lowest HR (154 - 166 bpm)[10]. Accordingly, elite French gymnasts presented the lowest mean HR values on the vault (144.5 bpm), compared to the floor (163.8 bpm), uneven bars (168.6 bpm), and balance beam (161.8 bpm)[1]. Mean relative intensities attained during simulated competition ranged from 65 to 85% of the VO_{2max} and HR_{max}[10]. These values are comparatively higher than the values reported in the present study (137 bpm, 69% of HR_{max}); however, such results should not be directly compared because rest intervals between exercises, the rest required for ice-treatment, and physiotherapy sessions during training were not excluded from analysis in the present study. Thus, our data may not elucidate the level of effort during WAG-specific exercises, even though they have the merit of characterizing the physiological demand of long training sessions (i.e., 4 h), during which gymnasts obviously cannot continuously perform vigorous activities. Furthermore, due to the explosive and quasi-maximal muscle contractions required and the cardiovascular strain induced by gymnastic performance, high HR values are expected while analyzing only competitive routines[10]. Finally, age and training/competition levels represent different conditions between ours and previous studies.

The mean value of 6.1 MET was stated for the WAG training sessions in the present study. Data related to metabolic rate in artistic gymnastics are not included in the compendium of physical activities[12]. The compendium reports MET values for a wide variety of physical activities, enhancing the comparability between studies. Accordingly, in the sports category, competitive cheer-

leading and gymnastic moves are described with a value of 6.0 MET[12]. Other sports activities with a similar MET corresponded to track and field (high jump, long jump, triple jump, javelin, and pole vault), competitive skateboard of vigorous effort, and competitive volleyball (6.0 MET for all). These data suggest that WAG training increased gymnasts' metabolic rate to values commonly observed in several other sports. Thus, metabolic rate and the resulting energy expenditure in WAG training sessions were quantified for the first time. Further, these responses were investigated in female children and teenagers, groups usually excluded from the exercise physiology and sports training studies.

The mean energy expenditure of WAG training sessions was 768.3 kcal, metabolic rate was 3.1 kcal.min^{-1} while TRIMP values corresponded to 239.2 ± 35.4 AU. Of note, we could not find any study in gymnastics quantifying energy expenditure, metabolic rate, and TRIMP, making it difficult to compare our findings with data obtained in the same sport. Using a similar method, Rodrigues et al.[24] estimated the metabolic rate (kcal.min^{-1}) and total energy expenditure (kcal) of professional futsal players during official matches. These authors reported a higher metabolic rate (18.1 kcal.min^{-1}), though lower total energy expenditure (313 kcal) compared to WAG training sessions. Further, during training sessions of male futsal players, Wilke et al.[19] reported an energy expenditure of 846 ± 129 kcal and a metabolic rate of 9.3 ± 1.0 kcal.min^{-1} while TRIMP values corresponded to 153 ± 21 AU. Previous studies monitored training session loads using TRIMP in different sports, such as female soccer (211 ± 81 AU)[25], basketball (215 ±109 AU)[26], taekwondo (114.3 ± 13.0 AU)[27] and swimming (107 ± 47 AU)[28]. However, comparisons between different sports are limited due to specific demands, sample characteristics, and TRIMP methods adopted in each study. Interestingly, TRIMP values were higher in gymnastics than in the studies mentioned above, which mostly included team sports, because of the long duration of gymnastic training sessions.

Participants of this study consisted of female gymnasts with a mean age of 10.9 years. Further, these gymnasts presented a low body fat (12.5 ± 2.0%) and a high training volume (4.08 ± 0.42 h per training session), cor-

Table 3 - Individual data for each artistic gymnastic training session.

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Average HR (bpm)										
Session 1	119	136	120	141	134	105	155	145	122	138
Session 2	120	130	133	151	145	136	141	130	116	152
Session 3	127	138	140	147	141	126	156	141	138	149
Session 4	118	134	131	143	122	143	160	148	149	148
Session 5	123	125	144	130	145	152	131	136	152	143
% HR max										
Session 1	61.7	69.1	62.6	65.8	63.9	56.6	76.6	72.7	61.9	69.8
Session 2	62.2	66.1	69.2	70.4	69.1	73.3	69.4	65.4	58.9	77.3
Session 3	65.5	70.0	72.8	68.6	67.3	68.3	76.6	71.0	70.1	75.7
Session 4	61.0	67.8	68.4	66.9	58.3	77.2	78.9	74.2	75.5	75.3
Session 5	63.7	63.5	74.8	60.6	69.6	82.2	64.3	68.2	77.3	72.7
EE (kcal)										
Session 1	616.9	905.9	739.0	991.9	773.2	511.0	628.7	620.0	548.7	575.0
Session 2	614.1	816.4	1132.8	1162.2	597.6	938.1	567.2	536.0	546.6	817.4
Session 3	715.6	905.8	1187.6	1232.2	885.3	828.5	715.5	659.0	611.2	652.3
Session 4	636.3	873.2	1049.0	980.6	649.6	1029.6	627.0	583.9	758.8	670.4
Session 5	587.9	727.2	936.0	851.9	887.4	1120.2	539.7	547.3	669.7	660.4
Metabolic rate (kcal/min)										
Session 1	2.5	3.8	3.0	4.3	3.2	2.1	2.7	2.5	2.3	2.5
Session 2	2.6	3.5	4.0	4.9	3.6	3.4	2.3	2.0	2.1	3.0
Session 3	2.9	3.9	4.0	4.6	3.5	3.0	2.7	2.4	2.9	2.9
Session 4	2.5	3.7	3.6	4.4	2.7	3.7	2.8	2.6	3.3	2.8
Session 5	2.7	3.3	4.2	3.7	3.7	4.1	2.0	2.2	3.5	2.7
MET										
Session 1	5.2	6.9	5.5	5.5	5.2	4.5	6.5	6.0	5.2	5.4
Session 2	5.2	6.3	7.1	6.2	6.0	7.3	5.5	5.0	4.7	6.5
Session 3	5.8	7.0	7.2	5.9	5.8	6.4	6.5	5.8	6.5	6.3
Session 4	5.0	6.6	6.5	5.6	4.4	8.0	6.8	6.2	7.4	6.2
Session 5	5.5	5.9	7.6	4.7	6.1	8.8	4.8	5.4	7.7	5.8
TRIMP										
Session 1	167.0	240.0	174.0	209.5	189.6	122.3	314.7	275.4	169.1	249.3
Session 2	170.9	210.4	241.0	255.4	241.5	284.9	244.2	204.0	138.9	323.0
Session 3	196.1	250.4	278.9	236.4	220.9	231.5	314.4	259.1	251.0	307.6
Session 4	159.2	226.9	234.2	219.5	130.9	323.5	335.4	289.4	304.0	303.8
Session 5	186.6	184.1	299.1	157.6	246.9	364.2	192.0	229.5	322.7	277.7

A1= athlete 1…, EE = energy expenditure, HR = heart rate, HR$_{max}$ = maximum heart rate, MET = metabolic equivalent of task, TRIMP = training impulse.

roborating previous reports for this population[13,29,30]. Knowing the mean energy expenditure during typical artistic gymnastic training sessions allows better diet control and, consequently, adequate energy supply for gymnasts' growth, daily activities, and athletic performance[13]. Thus, controlling energy balance is crucial to ensure gymnasts' health, preventing menstrual dysfunction, damage to bone development, and injuries[13,31]. Conversely, inadequate energy intake relative to energy expenditure compromises sports performance and can limit the benefits of training.

WAG is a strength-power activity with specific motor skills, whose energetic requirements are mainly anaerobic in nature due to the high intensity and short duration of competitive routines[5,32]. Thus, the main limitation of this study was that no physiological parameter quantified the contribution of anaerobic metabolism for energy transformation in skeletal muscles. Despite the

limited use of HR to quantify physiological strain associated with high-intensity intermittent activities, the artistic gymnastic training sessions reported here had a long duration (4 h), including long recovery intervals. Unarguably, under this condition, the most considerable contribution comes from aerobic pathways, making the current methodology valid and suitable to assess energy expenditure and effort intensity. Future studies should investigate physical and psychological parameters to ensure better characterization of WAG training sessions in young gymnasts.

The results of the current study have some practical applications: (1) the energy expenditure during training sessions may support the prescription of a proper diet according to the gymnast's requirements and (2) quantifying the training load by using HR and TRIMP measures supports training planning and periodization, for example, by comparing TRIMP values over training cycles.

Conclusion

Young female gymnasts who underwent prolonged (4.08 h) artistic gymnastic training sessions showed elevated energy expenditure, with average values of 768.3 kcal. Moreover, throughout the training sessions, the gymnasts performed efforts that, on average, can be characterized as moderate intensity, reaching average values of 69% of HR_{max}. Indeed, gymnasts spent most of the training sessions in intensities corresponding to less than 80% of HR_{max}. Altogether, these measurements contribute to characterizing the WAG training demands. Finally, considering the high energy expenditure reported, the training load control of these gymnasts must be accurately ensured.

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