Original Article

Performance indicators in individual rhythmic gymnastics: Correlations in competition

MARÍA A. FERNÁNDEZ-VILLARINO[1] ✉, ARIADNA HERNAIZ-SÁNCHEZ[1], ELENA SIERRA-PALMEIRO[2], MARTA BOBO-ARCE[2]

[1]*University of Vigo, Spain*
[2]*University of A Coruña, Spain*

ABSTRACT

The aim of this study was to identify the training variables that can determine the score in elite rhythmic gymnasts. Seven female rhythmic gymnasts participated in the study (age 15.7 ± 1.2). Performance data were collected from elite gymnasts (n=7) in competition exercises executed over 10 sessions occurring in the competition period. Additional variables such as heart rate, subjective rate of perceived exertion, competition category, number of apparatus, number of competitive exercises and number of training sessions were also collected. Data were examined using linear regression. Results showed that the heart rate average values ranged between 137 and 154 beats per minute. At the end of the competitive period, a decrease in the perceived exertion and the average score of the exercises were observed. An increase in the heart rate ($p < 0.01$) and in the perceived exertion ($p < 0.05$) has a positive impact on the total final score. The variables of heart rate and subjective rate of perceived exertion are significant to control the effects of training on the performance of individual rhythmic gymnasts. Moreover, they enable the coaches to control the training load in an affordable and reliable way. **Key words:** TRAINING LOADS, HEART RATE, RPE, RHYTHMIC GYMNASTICS.

Cite this article as:
Fernández-Villarino, M.A., Hernaiz-Sánchez, A., Sierra-Palmeiro, E., & Bobo-Arce, M. (2018). Performance indicators in individual rhythmic gymnastics: Correlations in competition. *Journal of Human Sport and Exercise, 13*(3), 487-493. doi:https://doi.org/10.14198/jhse.2018.133.01

✉ **Corresponding author.** *University of Vigo. Spain.*
E-mail: marianfv@uvigo.es
Submitted for publication February 2018
Accepted for publication March 2018
Published *in press* May 2018
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2018.133.01

INTRODUCTION

Training load control is a key factor to improve effectiveness and to prescribe specific training based on the needs of athletes (Harre, 1982; Platonov, 2001). In rhythmic gymnastics the most applied training control method is the assessment of the external load: i.e., specific training hours per week, number of repetitions of elements, parts and routines of the competition exercise, measuring the total time of each task or using the coaches' subjective assessment of the gymnasts' fatigue (Jastrejembskaia & Titov, 1999; Burt et al., 2010). However, these variables may not be sufficient to explain the individual response to the demands of training (Harre, 1982; Platonov, 2001).

The evaluation of the load in rhythmic gymnastics also requires the quantification of the intensity of the exercise performed and the number and complexity of all the contents that are included in the training session (Ávila-Carvalho et al., 2012; Botti & Nascimento, 2011). In this line, Tsopani et al. (2012) emphasize the importance that the increase of the coordination of the apparatus has on the training load, moreover that these abilities contribute in a significant way to the final score. In addition, the internal load of the gymnasts can be determined by the specific skills of the apparatus and body skills performed.

To the best of our knowledge, it would be necessary to increase the scientific evidence of the relationship between training loads and the competitive context. Several studies (Douda et al., 2006; Douda et al., 2008; Guidetti et al., 2000; Portier et al., 2006; Manos et al., 2012; Gateva, 2014) describe the use of physiological and psychological variables to determine the correct intensity of the training. Jointly, all these studies agree that the combination of physiological (such as heart rate, lactate, consumption oxygen) and psychological (rate of perceived exertion) parameters help to represent the intensity during training. However, some of the measured variables (i.e., VO2 max or lactate), and the situation in which they are measured (laboratory), do not seem to be adequate to the reality of training, to the means of the coaches, or to the ages at which this sport is practiced (Tokmakidis et al., 1996; Guidetti et al., 2000).

Despite the complexity of measuring the load in this sport (Jemni et al., 2011), it is necessary to define with precision the variables that can improve the process of sports training and especially when they affect the development of young athletes such as the case of rhythmic gymnastics. Moreover, there is a lack of scientific evidence that studies adaptations between loads in training situations and competitive context (Rutkauskaité and Skarbalius, 2011). Therefore, the purpose of the present study was to identify the elements of internal load that determine the score in elite rhythmic gymnasts. Additionally, we aimed to examine if there were differences in the previous indicators depending on the type apparatus: hoop, ball, clubs and ribbon.

METHODS

Participants

Seven female rhythmic gymnasts participated in the study, age 15.7 ± 1.2. All of them compete on a national level and belong to the same club. They trained together for an average of 23 hours per week and they have been practicing this sport for an average of 8.7 ± 1.2 years. The gymnast and their parents were all informed of the purpose and procedures of the study and they voluntarily agree to participate on it. A written consent form was also obtained from each subject or from their parents. The experimental protocol followed the Declaration Helsinki of World Medical Association for human research and was approved by the local Ethics Committee.

Measures

The dependent variable was the score achieved by gymnasts in the competition exercise executed in the main part of the training session (SCORE). The competitive exercises or routines were evaluated by four international judges following the protocol given by the International Gymnastics Federation (FIG, 2017-2020): difficulty (0-10 points) and execution (0-10 points) and goes from a maximum value of 20.00 points. The Kappa (K) values for inter-observer agreements ranged from 0.95-0.97.

Five independent variables were considered in the current study: (1) average heart rate (AHR); (2) subjective perceived exertion (RPE); (3) number of apparatus of the competition program: ball, hoop, clubs and ribbon (NA). Each gymnast could participate in more than one apparatus. Consequently, the value of these variables ranged from 1 to 4; (4) number of competitive exercises or routines completed in the session by the gymnasts (NE) and (5) number of training sessions completed in the competition period (NS). The value of this variable ranged from 1 to 10.

The instruments used for data collection were: (1) "Polar Vantage NTV" monitors for recording heart rate; (2) the CR-10 scale (Foster et al., 2001); (3) the official records of the competition exercises and (4) JVC digital cameras (GR-DVL820EA) to record the training sessions.

Procedures

The study was completed over 10 sessions during the competitive training period. Overall, each training season consisted of a 35-minute warm-up, 60-minute technical training, 35-minute simulated competition, and 15-minute cool-down. Data were collected using a modified 10-point RPE scale (CR-10, Foster et al., 2001) during the main part of the session, and each gymnast was monitored throughout the session with a Polar Vantage NTV monitor.

Statistical Analysis

Effects of independent variables on the score obtained by gymnastics were examined through a linear regression model. When estimating the regression models, we found no evidence of heteroscedasticity in residuals or multicollinearity among regressors. Moreover, the RESET test (Ramsey, 1969) did not reveal specification problems. RESET stands for regression specification error test. The detection of heteroscedasticity was done according to White's test. White's test is used to establish whether the residual variance of a variable in a regression model is constant. To test for constant variance, one regresses the squared residuals from a regression model onto the regressors, the cross-products of the regressors and the squared regressors. One then inspects the R2-value. Multicollinearity was checked using Klein's rule, which states that serious multicollinearity is present if the R2-value of the regression of a predictor variable on other predictor variables is higher than the R2 -value of the original regression. Since gymnastics are present between 4 and 10 times in the sample, all standard errors are clustered by players to account for non-independence in the data structure. Positive or negative coefficients for independent variables indicate that they have a positive or negative influence on the final score. β1 is the intercept and β2, β3, β4, β5 and β6 are the impacts of each of the independent variables. Finally, ε1 is the disturbance term. The model is as follows:

$$SCORE = \beta1 + \beta2 \cdot AHR + \beta3 \cdot RPE + \beta4 \cdot NE + \beta5 \cdot NA + \beta6 \cdot NS + \varepsilon1$$

Analyses were conducted using STATA (version 12.0, TX, USA). For analyses, statistical significance was maintained at $P < 0.05$.

RESULTS

The impact of the five independent variables on the score achieved by gymnasts is shown in Table 1. Heart rate ($p < 0.01$) and RPE ($p < 0.05$) had a positive impact on the overall final score. Each additional training session during the competitive period decreased the score by 0.32 points ($p < 0.01$).

The score achieved by gymnasts in Clubs is explained by the number of exercises. Each additional repetition of the competitive routine increased the score by 0.82 points ($p < 0.05$). The linear regression model explains 78% of the variance in the score. The score achieved by gymnasts in Hoop is explained by the RPE ($p < 0.01$), the number of exercises ($p < 0.01$) and the number of apparatus ($p < 0.05$). The linear regression model explains 77% of the variance in the score. The score achieved by gymnasts in Ribbon is explained by the number of exercises ($p < 0.01$). Each additional repetition increased the score by 1.74 points. The linear regression model explains 80% of the variance in the score. Finally, score achieved by gymnasts in Ball is explained by the number of exercises ($p < 0.01$) and the number of apparatus ($p < 0.05$). The linear regression model explains 87% of the variance in the score.

Table 1. Effects of variables on final score by apparatus and in total.

Independent variable	All Apparatus	Clubs	Hoop	Ribbon	Ball
AHR	0.04 (0.01)*	-0.02 (0.41)	-0.02 (0.54)	0.01 (0.63)	0.00 (0.89)
RPE	0.21 (0.02)**	-0.28 (0.09)	0.94 (0.01)*	-0.44 (0.06)	-0.24 (0.35)
Number of the exercises		0.82 (0.05)**	1.50 (0.00)*	1.74 (0.00)*	1.40 (0.00)*
Number of apparatus	-0.04 (0.89)	-5.09 (0.07)	3.32 (0.02)**	2.64 (0.14)	4.64 (0.00)*
Session	-0.21 (0.00)*				
Constant	6.89 (0.08)	49.59 (0.00)**	-12.85 (0.37)	-10.02 (0.33)	-14.63 (0.27)
Number of observations	66	66	65	66	66
R^2	0.63	0.78	0.77	0.80	0.87

AHR: Average Heart Rate; RPE: Rate of Perceived Exertion.
*P < 0.01
**P < 0.05

In accordance with the results displayed in Table 1, Table 2 presents the predicted score for rhythmic gymnasts depending on the values of the RPE and AHR. As can be seen, the predicted scores change dramatically depending on both variables. For example, if a gymnast has 130 beats per minute and a value of 6.5 in the RPE, the score would be 12.04; however, if the gymnast has 155 beats per minute and a value of 10 in the RPE, the score would be 13.96.

Table 2. Estimation of final grade in function of rate of perceived exertion (RPE) and average heart rate (AHR) for female senior gymnasts in the last session of training in a competitive period.

RPE	AHR					
	130	135	140	145	150	155
6.5	12.04	12.28	12.51	12.74	12.98	13.21
7.0	12.15	12.38	12.62	12.85	13.08	13.32
7.5	12.26	12.49	12.72	12.96	13.19	13.42
8.0	12.36	12.60	12.83	13.06	13.30	13.53
8.5	12.47	12.70	12.94	13.17	13.40	13.64
9	12.58	12.81	13.04	13.28	13.51	13.74
9.5	12.68	12.92	13.15	13.38	13.62	13.85
10	12.79	13.02	13.26	13.49	13.72	13.96

AHR: Average Heart Rate; RPE: Rate of Perceived Exertion.

DISCUSSION AND CONCLUSIONS

The aim of the current study was to identify the elements of the internal load that can determine the score in elite rhythmic gymnasts and analyze if there were differences depending on the type of apparatus. The main findings of this study indicated that the variables of heart rate and subjective rate of perceived exertion are significant to control the effects of training on the performance of individual rhythmic gymnasts. Moreover, they enable the coaches to control the training load in an affordable and reliable way.

Overall, the greater the values of AHR and RPE are, the better scores during the gymnastic rhythmic routine are achieved. Douda et al. (2008) found that heart rate is a significant variable in order to explain performance in gymnastics, especially with non-elite gymnasts. Similarly, Douda et al. (2006) suggest that the RPE is an appropriate indicator to describe the intensity of the exercise in elite gymnasts. Baldari and Guidetti (2001), indicated that parameters such as heart rate, developed at the anaerobic threshold, may be more reliable indicators of fitness level and may therefore be used to prescribe training. However, Portier et al. (2006) did not find any positive correlation between physiological parameters such as VO2max and heart rate and the score obtained for the gymnasts during competition. In agreement with Thompsen et al. (2007), the best results in sport are obtained using training protocols which are as specific as possible to the demands of the sport activity. The differences are possibly due to the type of measurement performed. It is not the same to measure in a laboratory situation with non-specific tests than in a real training situation. To our knowledge, there is only one study that compares lactate levels and heart rate between laboratory and competitive settings (Gateva, 2015). Where similar heart rate values were found between the settings (Gateva, 2015).

Concerning the influence of RPE and heart rate on the specific performance in each apparatus, the RPE was significant only in the case of the hoop. As a reason for this, we might point out that hoop presents higher technical versatility than the other apparatus and requires a complex coordination between body and apparatus (Ávila-Carvalho et al., 2012; Bozanic & Miletic, 2011). Furthermore, Portier et al. (2006) also recognize that the rope and clubs have a coordinating complexity that can increase the intensity of the load. These findings could indicate that the apparatus which demand higher technical versatility and difficulty requires a higher intensity during training (Caine et al., 2013).

The scientific evidence indicates that coaches seldom reflect about the effectiveness of the number of repetitions (Jemni et al., 2000). Concretely, the results obtained in this study indicate that the number of repetitions is an important variable to explain the final score which could increase 1.74 points for exercise performed. Despite this, authors such as Jemni et al. (2011) have observed the difficulty of measuring internal and external load in gymnastics, and the effects are therefore often underestimated by coaches. Hence, it is important that coaches learn to utilize load control strategies that would give adequate feedback on training adaptations.

The results suggest that heart rate, RPE and number of competitive exercise repetitions are variables to consider in order to control the effects of the training sessions on the performance of rhythmic gymnasts. High levels of heart rate and RPE increase the final score in competitive exercises. Similarly, a higher number of repetition of an exercise improves the final score, but this effect is apparatus specific. The findings can contribute to improve the effectiveness of training programs in rhythmic gymnastics. To design choreographies, the coaches should take into account that apparatus, e.g., hoop may require greater work intensities to obtain better results during competition. However, the results should be interpreted with caution due to the limitations of our study (small sample, number of routines observed and variables that allow the control of exercise intensity). Therefore, further studies are necessary to increase the knowledge regarding the training load of gymnasts in training and competition.

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