

Highlighted Article

Monitoring Workload and Performance Response to Taekwondo Training

Received 09th June 2017,
Accepted 24th June 2017

P. Carazo-Vargas,^{a,*} J. M. González-Ravé,^b J. Moncada-Jiménez,^{a,c} and F. González-Mohino,^b R. Barragán^b

www.ijpefs.com

DOI:10.26524/2017.06.02.1

^a School of Physical Education and Sports, University of Costa Rica, San José, 1200, Costa Rica.

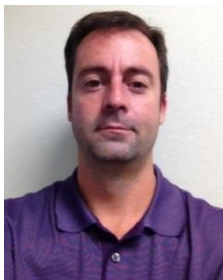
^b Sport Training Lab., Faculty of Sport Sciences, University of Castilla-La Mancha, Toledo, Av. Carlos III s/n 45071, Spain.

^c Human Movement Sciences Research Center (CIMOHU), University of Costa Rica, San José, 1200, Costa Rica

*Corresponding Author: Ph: +506- 2511 2755: Email: pedro.carazo@ucr.ac.cr

Abstract: This study compared the association between Foster's and Banister's TRIMP methods for quantifying internal training load and training stimuli responses. *Methods:* A group of twenty-two Taekwondo competitors were divided by gender and level of expertise. The athletes practiced three different types of exercises to develop the following skills: a) speed, b) power, and c) aerobic power. *Results:* A significant correlation was obtained between the Foster's and Banister's TRIMP methods for developing aerobic capacity ($r = 0.60$, $p = 0.004$) and power ($r = 0.52$, $p = 0.014$). No significant correlation was suggested between training methods and speed training ($r = 0.20$, $p = 0.377$). *Conclusion:* Lactate and heart rate responses to different types of exercises suggested the need for aerobic and anaerobic-based training sessions. The use of rating of perceived exertion scale-based measurements to monitor workload is recommended for Taekwondo competitors.

Key Words: Foster's method; Banister's TRIMP; lactate, heart rate; speed; aerobic power; Taekwondo



Pedro Carazo Vargas currently holds a Ph.D. in Human Movement Sciences from the National University and the University of Costa Rica. He represented his country internationally as a taekwondo competitor. After completing his stage as a competitor he was coach of the Costa Rican National Taekwondo

Team for 10 years, qualifying and participating as a coach at the Olympic Games Beijing 2008. He is currently a professor at the University of Costa Rica, where he teaches sports training courses and research methods in undergraduate and graduate courses. His research interests are mainly related to taekwondo, sports performance and meta-analytic technique, and currently focuses on the study of sleep and sports performance.



José María González-Ravé holds a Ph.D. in Sport Sciences. M.Sc in High Performance. Is currently the Principal Lecturer at the University of Castilla la Mancha (UCLM), for teaching and researching Theory and Methodology of Sport Training and Advances in Sport Training Research, master of sport sciences

and doctoral courses. Director from the Laboratory of Sport Training, that monitoring the sport performance of best spanish athletes a funded by the regional government of Castilla la Mancha. In the Laboratory, he heads the Human Performance research group. Secretary of Centre of Olympic Studies (COS) located in Castilla la Mancha (Spain). His research activity is mainly focused in peoriodization and methodology of sport training.



José Moncada-Jiménez holds a Ph.D. in Biomedical Sciences and is currently the Director of the Human Movement Sciences Research Center (CIMOHU) and a full-professor at the School of Physical Education and Sports of the University of Costa Rica, in San Jose, Costa Rica. He has published

extensively on topics related to sports medicine, training, research methods, statistics, and physical education. He has participated in more than 15 research projects with national and international funding, including cooperation with universities in México, USA, and Spain.



Rubén Barragán-Castellanos is a Ph.D. candidate at the University of Castilla-La Mancha, Spain. His current research focuses on swimming and triathlon performance. He has been author and co-author of different posters and communications in

international meetings.



Fernando González - Mohíno Mayoralas is a Ph.D. candidate at the University of Castilla-La Mancha, Spain. His current research is related to the energy cost of running in long and middle distance runners. Some of his publications are on the effect of continuous and interval training on

running economy. He has been author and co-author of different posters and communications in international meetings, and has also collaborated in research projects on swimming and triathlon performance.

Introduction

Taekwondo is an Olympic sport practiced by people of all ages from more than 206 countries worldwide. It is an individual combat sport in which one athlete fights against an opponent of the same weight, gender, and category, usually by a direct elimination system [1, 2].

In Taekwondo, the athlete's goal is to strike the opponent's torso and head with kicks and punches in the allowed target areas to accumulate points. Thus, technical execution, tactical moves, high power, and agility are required [3]. In a typical Taekwondo tournament, athletes fight in three-round bouts with each round lasting two minutes, and there are usually five bouts per day. Finally, physical conditioning objectives are focused on improving endurance, speed, and power [1, 2, 4, 5].

Various components are taken into account in order for training to achieve sporting success. For instance, training control and athlete's response to training stimulus are crucial elements to pursuing physiological adaptations [6]. Thus, analyzing gender and sports experience is essential to understanding the physiological responses to stimuli and evaluating the different load control methodologies during Taekwondo training.

A person's heart rate (HR) response to exercise has been considered a useful tool for

monitoring the internal training load (TL) in athletes [7]. The physiological rationale for using this technique is supported by the linear association between maximal work capacity (determined by a percentage of the maximal aerobic power, %VO₂max) and the maximal HR (HR_{max}) [8] and is considered advantageous, because it is non-invasive, inexpensive, and easy to measure.

Training load quantification in sports has drawn the attention of researchers in sports medicine and exercise sciences. This information is mandatory. The observed responses supported the importance of having adequate physical conditioning to meet the requirements for Taekwondo competition through both aerobic and anaerobic exercises to optimize athletic performance and avoid impairing an athlete's health [6]. Lactate response has been used for monitoring training load and effort during exercise [9]. In Taekwondo, lactate concentrations are related to the intensity and physical effort required to meet the anabolic demands during competition. Blood lactate measurement is practical and simple and only requires a single fingertip or earlobe blood test, which is analyzed easily on a portable device. Lactate measurement for training load control has been described in academic literature [10].

Physiological stress is also determined by recording an individual's perceived exertion and multiplying this figure by exercise endurance [11]. This method suggested by Foster et al. (2001) has been extensively used in sports such as basketball, Karate, soccer, cycling, water polo, and diving [12-17].

Another measurement approach for quantifying training load is named Training Impulse or TRIMP (TRaining IMPulse), based on HR measurements. Under this technique, minutes are multiplied by a specific intensity factor for both men and women [18]. This method was used as criteria to validate Foster's method in several athletic populations [13, 16, 17]. Edwards (1993) [19] and Lucia, Hoyos, Carvajal, and Chicharro (1999) [20] developed other ways based on HR measurements.

The use of session rating of perceived exertion (RPE) and HR measurement-based methods such as Banister's TRIMP and Edwards' Training Load in Taekwondo have shown concurrent and construct validity and equivalency for determining adolescent workload [21-23]. Nonetheless, these training load control methods have been under continuous scientific scrutiny to determine their usefulness and appropriateness in different sports and populations.

On the other hand, there is a lack of studies regarding monitoring progress of goals in Taekwondo adult athletes. The main purpose of this study was to analyze the association between Foster's and Banister's TRIMP methods for quantifying internal TL and comparing training stimuli responses between beginners and advanced Taekwondo adult competitors. A secondary aim was to verify the method's convergence as reported before [21, 23] in an adult competitor sample by considering their sport backgrounds.

Methods

Experimental Approach

This validation study investigated the convergence of Foster's TL method to quantify internal TL in adult Taekwondo performers. The TL obtained by Foster's method was compared to Banister's TRIMP method for quantifying internal TL. In addition, participants lactate and HR responses were analyzed by gender and expertise levels.

Participants

Twenty-two Taekwondo participants, 17 men (mean age = 23.9 ± 6.9 years) and 5 women (mean age = 21.0 ± 2.1 years) participated in this study, all of whom were volunteers and members of two Taekwondo clubs in two different cities in the autonomous community of Toledo, Spain. The two

clubs at different levels of training and competition experience (from white to black belts). For this reason, they were categorized as either beginners (mean experience = 0.28 ± 0.03 years of practice) or experienced performers (mean experience = 4.93 ± 5.20 years of practice).

Before beginning the study, all the participants were informed about the potential risks and benefits associated with their participation. Furthermore, they were fully trained on the research procedures and informed of their right to withdraw from the study at any time without penalty. Finally, those who agreed signed a written informed consent form meeting the principles of the Declaration of Helsinki [24].

Experimental Procedure

A familiarization period was provided to participants before they took part in the experimental phase. To achieve this, volunteers were required to rate various activities. Three different types of exercise trainings were designed to develop speed, power, and aerobic power based on the Foster method. Training data were collected over fourteen days.

During the first measurement session, participants were required to complete speed and power exercises. During the second measurement session, athletes were asked to complete aerobic power exercises. The practice sessions were intended to improve speed by resembling a Taekwondo match under coaching guidance. To do this, athletes were asked to kick a Taekwondo focus paddle pad every 10 seconds in four two-minute rounds with a one-minute break between rounds. Also, participants could attack or counterattack, participants executed between 1 and 4 kicks (from about 0.5 to 5 seconds). The person holding the focus pad moved freely and showed the mitt to the athlete depending on whether athletes were instructed to attack or counterattack. Participants were asked to give their maximum effort when performing each exercise.

For the activities intended to increase power, every subject performed a sequence of 45 jumps as well as a technical action involving kicking a mitt. Participants were encouraged to perform each sequence continuously at maximum effort, without any specific rhythm or preset time limit (every jump and technical execution lasted approximately 5 seconds). The first 15 attempts were squat jumps. Then, participants repeatedly performed two roundhouse kicks with the same foot. The next 15 jumps were counter-movement jumps and two roundhouse kicks alternating their feet. The last 15 jumps were Abalakov-type with a further execution of two roundhouse kicks simultaneously in the air [25].

The aerobic interval training consisted of four exercise sessions lasting 4-min each. Sessions were separated by a 4-min rest period. This regime allowed us to complete the sparring. Each bout consisted of a short duration high-intensity interval kicking exercise; for example 10:20 (a 10-s kicking exercise interspersed with a 20-s passive recovery.) Finally, during the warm-up, each athlete performed a kick, such as a roundhouse kick, repeatedly for 10-s at maximum effort. Verbal encouragements were provided to generate 90-95% of the athlete's maximal repeated kicks over the four bouts [21]. Fifteen minutes before starting the exercise, each participant performed a moderate jog and some stretching exercises. Every training session was performed in a Taekwondo gymnasium between 7:00 p.m. and 10:30 p.m. in a similar environment (19.97 ± 1.0 °C, $49.67 \pm 4.04\%$ relative humidity). To avoid dehydration, fluids were readily available to the athletes during all training sessions. In addition, instructions were given to the athletes to fast for a period of 3-4 hours before the training session and to fully hydrate before arriving at the exercise sessions rather than ingest stimulants.

Testing Procedures

Preliminary measurements for all participants included height, weight, body composition analysis (InBody230, Seoul, Korea), and jumping ability by three counter-movement jumps (CMJ) (OptoJump, Microgate, Italy). For the jumping exercises the best execution was recorded for further analysis. Training intensity during each exercise session was recorded every 5-second using an HR monitor (Suunto t3c, RECTA, Finland). Resting HR was measured following a 10-minute supine position. The HRmax was the highest HR value recorded for each athlete at the end of the exercise session. When training tasks included recovery periods, HR was recorded during both exercise and recovery. Finally, HR was measured 3-min following recovery.

Training Load Methods

For the Foster method, the 20-item scale obtained from the individual's rating of perceived exertion during the exercise session was used. This figure was then multiplied by the session duration. The Banister's TRIMP method [21], weighs the length of time using a weighting factor that applies the formula $TD \cdot HRR \cdot 0.64 \cdot e^{1.92 \cdot HRR}$ for men and $TD \cdot HRR \cdot 0.64 \cdot e^{1.67 \cdot HRR}$ for women, where TD is the effective training session duration expressed in minutes and HRR is heart rate reserve. HRR is determined by the following equation: $([HRTS - HRB] / [HRmax - HRB])$, where HRTS is the average training session HR, and HRB is the HR measured at rest (baseline).

Lactate Measurement

Blood lactate concentration was analyzed with the Lactate Scout analyzer (SensLab GmbH, Leipzig, Germany). A baseline resting lactate sample was obtained 10 minutes before starting the workout. Sampling was then scheduled 3 minutes after the end of each of the three exercise tasks.

Statistical Analyses

Statistical analyses were performed using the IBM SPSS for Windows version 20 (IBM Corporation, New York, USA). The results are presented as means \pm SD. The data normality was verified using the Shapiro-Wilk W test. The Pearson product-moment correlation coefficient was used to determine the convergent validity between Foster's TL and Banister's TRIMP. The meaningfulness of the correlation coefficients was evaluated using Hopkins' classification: ≤ 0.1 , trivial; 0.1–0.3 small; 0.3–0.5, moderate; 0.5–0.7, large; 0.7–0.9, very large; 0.9, nearly perfect; and 1.0, perfect [26]. In addition, Lin's concordance correlation coefficient was used to assess reproducibility between Foster' TL and Banister's TRIMP [27].

Table 1. Characteristics of participants according to training experience (n = 22)

	Beginners (n = 7)	Advanced (n = 15)	p =
Age (years)	21.9 \pm 2.3	24.1 \pm 7.3	0.449
Height (cm)	173.43 \pm 5.22	174.17 \pm 7.35	0.815
Weight (kg)	70.43 \pm 4.63	71.75 \pm 8.32	0.702
BMI (kg/m ²)	23.44 \pm 1.47	23.4 \pm 2.2	0.918
Body fat (%)	18.98 \pm 9.93	16.0 \pm 7.2	0.438
Waist/hip ratio	0.82 \pm 0.02	0.83 \pm 0.03	0.894
Jump height (cm)	28.6 \pm 6.6	33.2 \pm 5.4	0.104
Basal HR (beats·min ⁻¹)	53.4 \pm 10.3	55.0 \pm 5.4	0.640

BMI: Body mass index. HR: Heart rate

Lin's strength of agreement (ρ_c) was considered poor (< 0.90), moderate ($0.90 - 0.95$), substantial ($0.95 - 0.99$), or almost perfect (> 0.99) [27, 28].

Analysis of variance (ANOVA) was computed to determine HR and lactate concentration differences according to gender and practical experience in response to the different tasks. Significance was set a priori at $p < 0.05$.

Results

Descriptive statistics according to training experience for age, weight, height, BMI, body fat percentage, waist/hip ratio and jump power are presented in Table 1.

The results of the ANOVA showed no significant interactions between gender and training experience. However, gender differences were found in body fat percentage ($p < 0.0001$) and jump performance ($p < 0.0001$), where men revealed a lower fat percentage ($13.5 \pm 4.8 \%$) and jumped higher ($33.9 \pm 4.6 \text{ cm}$) than women ($28.9 \pm 4.4 \%$ and $24.3 \pm 4.1 \text{ cm}$). No significant differences were observed for the main training experience effect. A significant Pearson correlation was found between

Foster's and Banister's TRIMP methods for resistance training ($r = 0.60, p = 0.004$) and power training ($r = 0.52, p = 0.014$). No significant Pearson correlation was observed between the two methods with speed training ($r = 0.20, p = 0.377$). Lin's concordance coefficient between Foster's and

Banister's TRIMP methods for resistance ($R_c = 0.00, CI_{95\%} = 0.00-0.01$), speed ($R_c = 0.00, CI_{95\%} = -0.00-0.01$), and power training ($R_c = 0.01, CI_{95\%} = 0.00-0.0$) were low.

The HR responses during aerobic power training were different over time ($p < 0.0001$). There was a clear trend that showed increases during execution and decreases during periods of rest and recovery (Figure 1). Bonferroni post hoc analyses suggested differences between each of the four exercise and resting periods, as well as between the last measurements made three minutes following recovery. Women demonstrated different HR after recovery including the other measurements. During power training, a difference between each of the measurements was determined, and there was a significant increase and recovery in HR at the end of the practice.

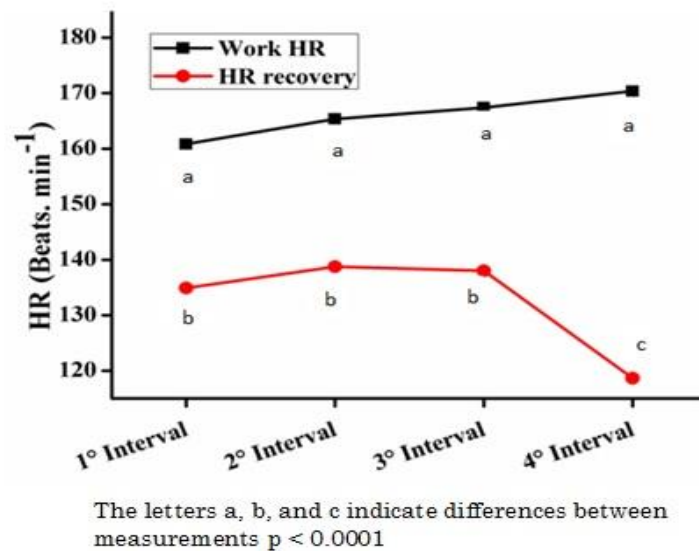


Figure 1. Heart rate response between measurements in endurance training

As shown in Figure 2, significant correlation between gender, experience, and measurements was obtained in speed training ($p < 0.011$). The two experience conditions increased their HR during exercise and achieved a significant recovery in the following 3-minute exercise. A significant difference was found between male and female advanced athletes in HR recovery ($p < 0.05$). Differences between the first round measurement and the other

measurement periods and between the first resting period and the other measurement times ($p < 0.05$) were observed. A difference between the recovery measurement and all other measurements was determined in a male beginner group. In this group, an increased HR at the end of the fourth round was observed compared to the HR recorded during the second round, third round, and the resting period of the second round ($p < 0.05$). Women beginners also

showed an elevated HR at the end of the fourth round compared to the measurements in the second and third round as well as the resting period of the second round ($p < 0.05$). Although no significant recovery was observed in the last measurement time, a significant interaction between genders was noted, both for advanced Taekwondo practitioners and

beginners ($p < 0.05$). Beginner women showed lower HR responses from the second round measurement to the second round resting period ($p < 0.05$). A higher HR response was observed in beginner men compared to beginner women in the second round measurement ($p < 0.05$).

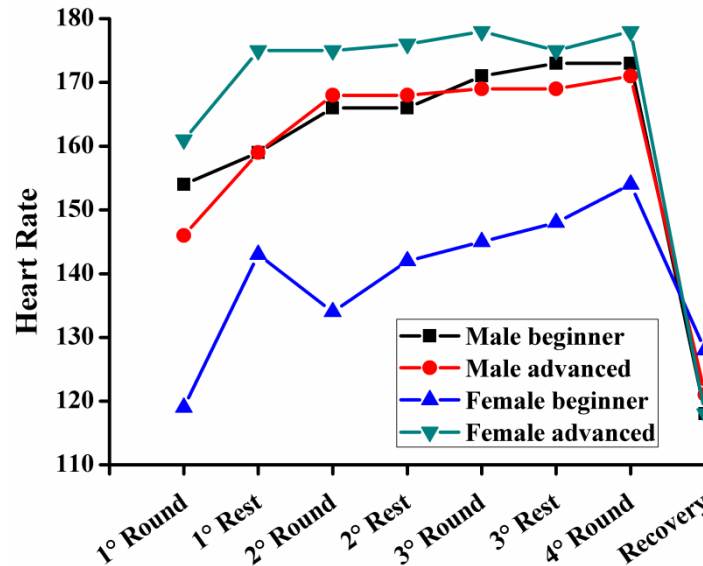


Figure 2. Heart rate changes between measurements in speed training

No significant interactions between gender and experience were found on the lactate response in training exercises ($p > 0.05$). Significant differences were noticed between the three different resistance measurements: time ($p < 0.001$), power ($p < 0.001$), and speed ($p < 0.001$). The initial lactate concentration in the aerobic power training was significantly lower (1.8 ± 0.5 mmol/l) than the immediate following exercise (11.4 ± 3.5 mmol/l) and after the 3-minute recovery period (10.4 ± 2.9 mmol/l) ($p < 0.05$). The initial lactate concentration in power training was significantly lower (1.7 ± 0.6 mmol/l) than the immediately following exercise (11.5 ± 3.3 mmol/l) and after the 3-minute recovery period (9.5 ± 2.9 mmol/l) ($p < 0.05$). The initial lactate concentration in the speed training was significantly lower (1.7 ± 0.6 mmol/l) than the immediate following exercise (10.0 ± 3.0 mmol/l) and after the 3-minute recovery period (8.0 ± 2.9 mmol/l) ($p < 0.05$).

Discussion

The aim of the study was to examine the association between Foster’s and Banister’s TRIMP methods for quantifying internal TL and to compare Taekwondo beginners and advanced athletes’ physiological responses.

The main findings of this research suggested that Foster’s and Banister’s TRIMP methods have a low convergent validity. Consequently, the application of these methods in adult Taekwondo training should be carefully analyzed, and there should be a focus on selecting the most appropriate methodology for this population.

Previous research [21] has demonstrated moderate to high correlations ($r = 0.55-0.90$; $p < 0.001$) between Foster’s and Banister’s TRIMP methods for quantifying internal TL in junior Taekwondo athletes (13.1 ± 2.4 years). However, the findings of the present study suggested that TL quantification using the these methods might not be identical given the nature of Taekwondo training [1].

Furthermore, divergent validity between the two TL methods was found following replication of an aerobic training protocol previously used in Taekwondo athletes [23]. In the current study, Foster’s and Banister’s TRIMP methods for quantifying internal TL were moderately associated ($r = 0.60$, $p = 0.004$), which are in contrast to a previous study [23] in which the results showed $r = 0.14$ ($p > 0.05$).

The association between Foster’s and Banister’s TRIMP methods for quantifying internal TL reported in the present study has been found in

aerobic exercise in the junior athletes participating in a training camp ($r = 0.60$, $p > 0.001$) [23]. Likewise, the relationship found in power training ($r = 0.52$, $p = 0.014$) was similar to that reported for training sessions using plyometric, speed, or intermittent exercises ($r = 0.32$, $p > 0.05$).

In the present study, Foster's and Banister's TRIMP methods for quantifying internal TL showed significant correlation coefficients. However, convergent validity between the two methods in terms of feasibility and accuracy require further research. Conclusions drawn from simple correlational analysis (e.g., Pearson) were insufficient to support the interchangeability of Foster's and Banister's methods for concordance between any two methods requires the application of other analytical techniques [29]. For instance, Lin's concordance coefficient correlation would be a necessary technique to estimate the association between the two measurement methods [27]. In addition to being reproducible, Lin's concordance combines the precision and accuracy to determine to what extent the observed data from both methods deviate from perfect agreement [29, 30]. Indeed, based on Lin's statistic (1989) [27], we observed poor concordance coefficients between Foster's and Banister's TRIMP as well as among TL methods for aerobic, speed, and power training.

Taekwondo training and competition is an intermittent sport in nature and requires high-intensity intervals interspersed with low-intensity intervals. The high-intensity intervals rely on anaerobic metabolism, and heart rate is dramatically increased during training and competition [9, 23, 31-33]. Since intermittent training may reduce the degree of correlation between perceived exertion (e.g., the Foster's method) and other methods (e.g., Banister's TRIMP) [13], this feature might also explain the weak convergence found between Foster's and Banister's TRIMP TL methods. In addition, Foster's method (i.e., RPE) has been suggested as a convenient and practical approach for monitoring TL when a combination of aerobic and anaerobic metabolism is present in other sports such as Taekwondo [31, 34, 35]. It is also important to consider other variables such as anxiety and stress that might negatively affect an individual's RPE during demanding scenarios such as training, especially during competition [36].

Further reliability studies on Foster's method during intermittent competition and training studies in Taekwondo are required. These studies are especially important when analyzing contact sports where the response to the same stimuli is likely to be different. For instance, kicking drills and combat strategy in Taekwondo are selected based on the

opponents' characteristics; therefore, these drills are often modified during training and competition.

The participants of this study had similar physical characteristics to those previously reported. Participants in this study reported similar jump height values to those indicated in elite competitors, including men and women [36, 37]. Yet, this variable did not seem to differentiate between elite and a non-elite Taekwondo competitors. Adiposity, as determined by body fat percentage, ranges from 7-14% in men and 12-19% in women. These values were similar to those reported for Taekwondo male competitors ($13.5 \pm 4.8\%$), but were different from those of female competitors ($28.9 \pm 4.4\%$) [37-41].

A correlation between the participants' characteristics and those previously reported in other competitions was found in this study. In addition, similar training stimuli responses by sex and training experience were observed. This aspect supports the generalizability of the findings reported on TL methods. Physiological responses (i.e., HR and lactate) reported in this study were consistent with previous reports. For instance, adolescent Taekwondo men showed an increase in HR (63 ± 8 beats min^{-1} to 201 ± 6 beats min^{-1}) following an aerobic training regimen [23]. Acute changes in HR were also described following training drills similar to those used in this study (e.g., kicking a striking shield or combat simulations), where HR increased from the baseline to 148 ± 15 beats min^{-1} and 160 ± 17.4 beats min^{-1} [32]. Responses in HR during competition were also documented, changing from prior to the beginning of the bout (53 ± 3 beats min^{-1}), the beginning of the first round (175 ± 15 beats min^{-1}), and up to the end of a combat (199 ± 3 beats min^{-1}) [2, 9, 31, 33].

Post-exercise blood lactate increments following 220 s of physical exertion (baseline = 1.8 ± 0.6 mmol/l vs. post-exercise = 10.3 ± 2.5 mmol/l) [37] were similar in the present study (baseline = 1.7 ± 0.6 mmol/l versus. post-exercise = 11.4 ± 1.7 mmol/l). Lactate concentrations measured in Taekwondo competitors during official tournaments and simulation fights have shown high variability, ranging from 7.0 ± 1.5 mmol/l to 12.2 ± 4.6 mmol/l [2, 4, 9].

Evidence suggested that the blood lactate concentration is sensitive to changes in training intensity [42]. In this research, neither a mean increment in lactate values according to training modality was observed nor significant differences in participants' training experience. The observed responses supported the importance of having adequate physical conditioning to meet the requirements for Taekwondo competition through both aerobic and anaerobic exercises.

With regard to lactate levels, the use of HR and RPE to monitor TL looks appealing due to the fact that these techniques are non-invasive and reasonably inexpensive. The use of HR is widely accepted in endurance sports. However, its use is questionable in speed or power training and shows a lack of a significant cardio-respiratory component [6]. Therefore, the evidence supports the use of RPE-based measurements on TL control in Taekwondo.

Conclusions

Given the lack of convergent validity between Foster's and Banister's TRIMP TL methods, we consider that these two techniques should not be used interchangeably to quantify the TL in Taekwondo competitors.

It is inconvenient to use the TRIMP Banister to accurately quantify the training load in Taekwondo competitors. Taking into account the diversity of dynamic training and intermittent exercise characterized by the prevalence of anaerobic metabolism regardless of their experience, Banister TRIMP use is not recommended in this group of athletes. Monitoring the response to stimuli in athletes' training is a key factor to achieve the objectives pursued. Quantification of Taekwondo training is recommended by Foster's method, especially considering the necessity of having new studies to support its reliability in a variety of environments.

Acknowledgements

We would like to express our gratitude to Prof. Geannette Soto and Mr. Andre Moskowitz for their expert review of the manuscript.

References

- [1] P. Carazo-Vargas, González-Ravé, M. José, U. Newton, Robert, Moncada-Jiménez, José, Periodization Model for Costa Rican Taekwondo Athletes *Strength and Conditioning Journal*, 37 (2015) 74-83.
- [2] C. Bridge, M. Jones, and B. Drust, hysiological Responses and perceived exertion during international taekwondo competition, *International Journal of Sports Physiology and Performance*, 4 (2009) 485-493.
- [3] V. Santos, E. Franchini, and A. Lima-Silva, Relationship between attack and skipping in taekwondo contests, *Journal of Strength and Conditioning Research*, 25 (2011) 1743-1751.
- [4] P. Carazo-Vargas, Respuestas y adaptaciones fisiológicas al entrenamiento de taekwondo. Una revisión sistemática, *Pensar en Movimiento: Revista de Ciencias del Ejercicio y la Salud*, 11 (2013) 1-19.
- [5] M. Kazemi, M.G. De Ciantis, and A. Rahman, A profile of the Youth Olympic Taekwondo Athlete, *Journal of the Canadian Chiropractic Association*, 57 (2013) 293-300.
- [6] J. Borresen, and M. Lambert, The Quantification of Training Load, the Training Response and the Effect on Performance, *Sports Medicine*, 39 (2009) 779-795.
- [7] J. Achten, and A. Jeukendrup, Heart Rate Monitoring, *Sports Medicine*, 33 (2003) 517-538.
- [8] F. Arts, and H. Kuipers, The relation between power output, oxygen uptake and heart rate in male athletes, *International Journal of Sports Medicine*, 15 (1994) 228-231.
- [9] CA. Bridge, LR. McNaughton, GL. Close, B. Drust, Taekwondo exercise protocols do not recreate the physiological responses of championship combat, *International Journal of Sports Medicine*, 34 (2013) 573-581.
- [10] L. Tjelta, A longitudinal case study of the training of the 2012 European 1500 m track champion, *International Journal of Applied Sports Science*, 25 (2013) 11-18.
- [11] C. Foster, JA. Florhaug, J. Franklin, L. Gottschall, LA. Hrovatin, S. Parker, P. Doleshal, C. Dodge, A new approach to monitoring exercise training, *Journal of Strength and Conditioning Research*, 15 (2001) 109-115.
- [12] CG. Freitas, MS. Aoki, CA. Franciscan, AF. Arruda, C. Carling, A. Moreira, Psychophysiological responses to overloading and tapering phases in elite young soccer players, *Pediatric Exercise Science*, 26 (2014) 195-202.
- [13] FM. Impellizzeri, E. Rampinini, AJ. Coutts, A. Sassi, SM. Marcora, Use of RPE-based training load in soccer *Medicine and Science in Sports and Exercise*, 36 (2004) 1042-1047.
- [14] C. Lupo, L. Capranica, and A. Tessitore, The validity of the session-RPE method for quantifying training load in water polo, *International Journal of Sports Physiology and Performance*, 9 (2014) 656-660.
- [15] C. Minganti, L. Capranica, R. Meeusen, and M.F. Piacentini, The Use of Session-RPE Method for Quantifying Training Load in Diving, *International Journal of Sports Physiology and Performance*, 6 (2011) 408-418.
- [16] J. Padulo, et al., *Science, Movement and Health*, 14 (2014) 182-185.
- [17] Jose A. Rodri'Guez-Marroyo, gerardo Villa,JJuan Garcí'A-Lo'Pez,and Carl Foster, Comparison of Heart Rate and Session RPE Methods of Defining Exercise Load in Cyclists, *Journal of Strength and Conditioning Research*, 26 (2012) 2249-2257.

- [18] E. Banister, and T. Calvert, Planning for future performance: Implications for long term training, *Canadian Journal of Applied Sport Sciences Journal Canadien des Sciences Appliquees au Sport* 5 (1980) 170-176.
- [19] S. Edwards, The heart rate monitor book. Sacramento, CA: Fleet Feet Press, 1993,
- [20] A. Lucia, J. Hoyos, A. Carvajal, J.L. Chicharro, Heart rate response to professional road cycling: the Tour de France *International Journal of Sports Medicine*, 20 (1999) 167-172.
- [21] M. Haddad, A. Chaouachi, C. Castagna, D.P. Wong, D.G. Behm, K. Chamari, The Construct Validity of Session RPE During an Intensive Camp in Young Male Taekwondo Athletes, *International Journal of Sports Physiology and Performance*, 6 (2011) 252-263.
- [22] M. Haddad, A. Chaouachi, C. Castagna, P. Wong del, K. Chamari, The convergent validity between two objective methods for quantifying training load in young Taekwondo athletes, *Journal of Strength and Conditioning Research*, 26 (2012) 206–209.
- [23] M. Haddad, M. Haddad, A. Chaouachi, D.P. Wong, C. Castagna, K. Chamari, Heart Rate Responses and Training Load During Nonspecific and Specific Aerobic Training in Adolescent Taekwondo Athletes, *Journal of Human Kinetics*, 29 (2011) 59-66.
- [24] W.M. Association, WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects. [cited 2016 June 21]; Available from: <http://www.wma.net/en/30publications/10policies/b3/>.
- [25] E. Sáez-Sáez de Villarreal, B. Requena, and R. Newton, Does plyometric training improve strength performance? A meta-analysis, *Journal of Science and Medicine in Sport*, 13 (2010) 513-522.
- [26] W.G. Hopkins, Measures of reliability in sports medicine and science, *Sports Medicine*, 30 (2000) 1-15.
- [27] L. Lin, A Concordance Correlation Coefficient to Evaluate Reproducibility, *international Biometric Society*, 45(1) (1989) 255-268.
- [28] G.B. McBride, Using statistical methods for water quality management: issues, problems and solutions, Hoboken (New Jersey): Wiley-Interscience. xxiv, 313 p. p
- [29] Maria Inês B Silva, Barbara S Vale, Carla C S Lemos, Marcia R S G Torres, Rachel Bregman, Body Adiposity Index Assess Body Fat with High Accuracy in Non-dialyzed Chronic Kidney Disease Patients, *Obesity*, 21 (2013) 546-552.
- [30] RN. Bergman, D. Stefanovski, TA. Buchanan, AE. Sumner, JC. Reynolds, NG. Sebring, AH. Xiang, RM. Watanabe, A better index of body adiposity, *Obesity* (Silver Spring, Md), 19 (2011) 1083-1089.
- [31] E. Bouhlel, A. Jouini, N. Gmada, A. Nefzi, K. Ben Abdallah, Z. Tabka, Heart rate and blood lactate responses during Taekwondo training and competition, *Science & Sports*, 21 (2006) 285–290.
- [32] CA. Bridge, MA. Jones, P. Hitchen, X. Sanchez, Heart rate responses to Taekwondo training in experienced practitioners, *Journal of Strength and Conditioning Research*, 21 (2007) 718-723.
- [33] G. Markovic, V. Vucetic, and M. Cardinale, Heart rate and lactate responses to taekwondo fight in elite women performers, *Biology of Sport*, 25 (2008) 135-146.
- [34] L.A. Perandini, T.A. Siqueira-Pereira, N.M. Okuno, L.F. Soares-Caldeira, F.Y. Nakamura, Use of session RPE to training load quantification and training intensity distribution in taekwondo athletes, *Science & Sports*, 27 (2012) e25-e30.
- [35] L.F. Soares-Caldeira, N.M. Okuno, M. Magalhães-Sales, C.S.Campbell, H.G.Simões, F.Y. Nakamura, Similarity in physiological and perceived exertion responses to exercise at continuous and intermittent critical power, *European Journal of Applied Physiology*, 112 (2012) 1637-1644.
- [36] S. Chiodo, A. Tessitore, C. Cortis, G. Cibelli, C. Lupo, A. Ammendolia, M. De Rosas, L. Capranica, Stress-related hormonal and psychological changes to official youth taekwondo competitions, *Scandinavian Journal of Medicine & Science in Sports*, 21 (2011) 111–119.
- [37] E. Casolino, C. Cortis, C. Lupo, S. Chiodo, C. Minganti, L. Capranica, Physiological Versus Psychological Evaluation in Taekwondo Elite Athletes, *International Journal of Sports Physiology and Performance*, 7 (2012) 322-331.
- [38] C. Bridge, S. Santos, H. Chaabène, W. Pieter, E. Franchini, Physical and Physiological Profiles of Taekwondo Athletes, *Sports Medicine*, 44 (2014) 713-733.
- [39] B. Ghorbanzadeh, S. Mündroğlu, C. Akalan, M. Khodadadi, S. Kdrzaci, M. Şahdn, Determination of Taekwondo National Team Selection Criteria by Measuring Physical and Physiological Parameters, *Annals of Biological Research*, 2 (2011) 184-197.
- [40] W. Thompson, W. and C. Vinueza, Physiologic profile of Tae kwon Do black belts, *Sports Medicine, Training and Rehabilitation*, 3 (1991) 49-53.
- [41] N. Toskovic, D. Blessing, and H.N. Williford, Physiologic profile of recreational male and female novice and experienced Tae Kwon Do practitioners, *Journal of Sports Medicine and Physical Fitness*, 44 (2004) 164-172.
- [42] R. Beneke, R. Leithauser, and O. Ochentel, Blood lactate diagnostics in exercise testing and training, *International Journal of Sports Physiology and Performance*, 6 (2011) 8-24.