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# FATIGUE MONITORING: A CASE STUDY IN WOMEN'S PROFESSIONAL BOXING

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**Summary**. The objective of this research was to present a model for monitoring fatigue that could be used in Boxing, so that coaches have a tool to control their athletes during the training and tuning process. The article provides a case study of a professional boxer, with whom fatigue monitoring was carried out prior to a world title fight in the lightweight category, using as indicators the height of jumps, speed of straight punches and a subjective perception questionnaire on sleep quality, stress level, fatigue and muscle pain. At the end of the monitoring process, improvements were obtained in the height reached for all jumps and in the isolated straight left jabs, as well as a reduction in the accumulation of fatigue indicators, reflecting the possibility of considering the use of similar models with the objective of controlling the training process and optimizing performance.

**Key words:** Fatigue, performance, recovery, boxing.

# MONITOREO DE LA FATIGA: UN ESTUDIO DE CASO EN BOXEO PROFESIONAL FEMENINO

**Resumen**. El objetivo de esta investigación fue presentar un modelo para el monitoreo de la fatiga que pudiera ser utilizado en Boxeo, a fin de que los entrenadores dispongan de una herramienta para el control de sus deportistas durante el proceso de entrenamiento y puesta a punto. El artículo provee el estudio del caso de una boxeadora profesional, con la que se llevó a cabo el monitoreo de la fatiga previo a una disputa por los títulos mundiales de la categoría ligero, utilizando como indicadores la altura de saltos, velocidad de golpes rectos de puño y un cuestionario de percepción subjetiva sobre la calidad del sueño, nivel de estrés, fatiga y dolor muscular. Al finalizar el proceso de monitoreo se obtuvieron mejoras en la altura alcanzada para todos los saltos y en los golpes rectos aislados de izquierda, así como una reducción en la acumulación de los indicadores de fatiga, plasmando la posibilidad de considerar el uso de modelos similares con el objetivo de controlar el proceso de entrenamiento y optimizar el rendimiento.

**Palabras clave:** Fatiga, rendimiento, recuperación, boxeo.

## Introduction

Fatigue monitoring is a strategy from which with the use of different tools, it is possible to know the responses of athletes to a given physical exercise load (Gabbett et al., 2017). In this way, it is possible to know if the adaptations to training are those sought during the different phases of the periodization (Halson, 2014)in order to avoid an accumulation of stress that could lead to overtraining or even a detriment to health (Drew & Finch, 2016; Hamlin et al., 2019).

While it has been postulated that fatigue is a requirement for activating the supercompensation and capacity enhancement mechanisms in athletes (Wada et al., 2020)it should be controlled in order to avoid a stagnation or reduction of performance due to a wrong dosage of training loads (Mukhopadhyay, 2021). An adequate regulation of fatigue is essential, especially during *tapering* periods, since in these cases athletes must be allowed to recover properly without loss of adaptations in order to arrive in optimal conditions to the competition (Le Meur et al., 2012).

In order to carry out fatigue monitoring, assessments on neuromuscular function, such as the height of different types of jump and the quality of execution of some specific gestures have been proposed (Coutts et al., 2007; Gathercole et al., 2015; Halson, 2014; Kennedy & Drake, 2017)as well as subjective perception questionnaires, using indicators such as level of fatigue, sleep quality, muscle aches and stress (Chen et al., 2022; Hooper et al., 1995; Ramírez-López et al., 2022; Thorpe et al., 2016),

Boxing is a sport in which muscle strength-power levels are an indicator of performance efficiency and one of the most important factors in the damage produced by the blows (Rezzonico, 2022)for this reason, its appropriate development would be one of the main objectives sought in training plans. In this context, punch force analysis can be used as a diagnostic tool for the design and control of exercise programs (Lenetsky et al., 2013). Considering that a relationship has been found between the speed reached by the hand and the force applied in the strokes (Mack et al., 2010)in cases where force cannot be directly evaluated, speed could be considered as a valid performance parameter.

In this activity, participants are classified according to different weight categories, so those who perform it competitively usually adjust their body composition by maximizing muscle content and limiting fat tissue (Chaabène et al., 2015). In order to reach the desired or agreed weight, caloric restrictions, decreased fluid intake and/or use of coats to increase body fluid loss are often carried out (Barley et al., 2019; Pallarés et al., 2016). There is a high risk of compromising performance when the dosage of loads exceeds the energy and hydric possibilities (Burke et al., 2021) (Burke et al., 2021)a situation that even leads to a greater likelihood of injury, due to a direct relationship between its incidence and increased fatigue (Drew & Finch, 2016).

According to the above, fatigue monitoring would be a good way to know the effects of training and control the process, being in the case of boxers a very useful option to regulate their preparation and thus optimize performance, considering the possibility of adverse nutritional conditions or an overload due to accumulation of work. Taking this into account, this article studies a case in which fatigue monitoring was carried out in a female professional boxer during the four weeks prior to a lightweight world title fight.

### *Characteristics of the athlete*

The boxer who participated in the study began her professional career in 2013, having 9 years of experience and a total of 19 fights under her belt at the time of the intervention. Throughout his career he competed in the feather (55.3 - 57.1 kg) and super feather (57.1 - 58.9 kg) categories. His experience in Strength-Power training goes back to his beginnings in the professional field, carrying out 3 weekly stimuli of this type of work uninterruptedly (except for periods of vacation breaks and an interval of 3 months for pregnancy), which usually included: *core*exercises, plyometric, derived from Olympic weightlifting, ballistic, basic strength and accessories. In addition to the aforementioned work, the fighter kept a load of 6 weekly stimuli (Monday to Saturday) of boxing training of approximately 60-90' of duration, which were performed in a first shift during the morning hours (10 to 12hs approximately).

Since women's boxing still does not receive the same economic income as men's boxing, the athlete has always had to work as a teacher to earn extra money. This was considered at the time of scheduling her training sessions, since she did not have all the time outside of them for her breaks, but rather they were conditioned by her daily activities.

Regarding the nutritional area, the fighter received support on some occasions from specialists in the area who provided her with a program adjusted to her activity, but this was not sustained in the long term. In any case, she remained at approximately 5-10% of the categories in which she competed, and this percentage was not exceeded except during the period of her pregnancy.

***Characteristics of the competition***

The bout for which this work was carried out was agreed in the lightweight category (58.9 - 61.2 kg) and was a dispute for the titles of the World Boxing Council (WBC), World Boxing Association (WBA), International Boxing Federation (IBF) and World Boxing Organization (WBO).

The boxer carried out all the preparation in her country of residence, but had to travel a week before the fight to the country where the contest would take place. The evaluations were carried out up to one week before the combat, since due to travel and distance it was not possible to monitor the variables during this last period.

***Strength-Power Training Program***

Table 1

*Strength-Power Training Program*

| TYPE OF EXERCISE | EXAMPLES | VOLUME | INTENSITY |
|---|---|---|---|
| **CORE** | Rotations with elastic band, Press pallof, Bicho Muerto, Anti-Throwing, Anti-Throwing, etc | 3-4 series | Moderate |
| **PLIOMETRY** | Variations of jumps minimizing the contact time on the floor | 3-4 series of 30-40 jumps | Maximum |
| **POWER** | *Hang Power Snatch/Clean, Jerk* | 3-5 sets of 3-4 repetitions | 70-85% 1RM |
| **BALISTIC** | Medicine ball throws | 4-3 series of 10-12 pitches | 5-10% PC |
| **FORCE** | Squats, Flat Bench Strength, Hip Thrusts | 3-4 sets of 12-6 repetitions | 30-60% 1RM |

*Note:* Ihe intensity is represented according to the percentage of Body Weight (BW) and the maximum repetition in the exercise (1RM).

Table 1 shows how the Strength-Power training program was conformed, which consisted of 3 weekly training sessions that took place at noon (13hs) on Mondays, Wednesdays and Fridays, with approximately one hour of rest interval with respect to their boxing work.

During the 4-week period in which it was developed and with the objective of reaching a peak performance at the time of combat, a gradual reduction in volume was carried out while maintaining the intensity thus respecting the principles of a precompetitive *tapering* (le Meur et al., 2012). An ATR (Accumulation, Transformation, Realization) periodization model was used, which has great application in the case of professional boxers (Rezzonico, 2022)the beginning of the last period (Realization) was made to coincide with the beginning of the fatigue monitoring process.

## Method

The methodology used for this study was quantitative, since it was based on the treatment of numerical data which were extracted from the periodic evaluations carried out with the boxer. On the other hand, the work was longitudinal and intensive, since the study was carried out in depth on a single case during a period of four weeks. The research design was descriptive, with a detailed analysis of the results of the tests used.

### *Measuring Instruments and Techniques*

Data collection for fatigue monitoring was carried out 3 times per week, on the same days that Strength-Power was trained. For this purpose, once the pre-activation consisting of *core* exercises had been completed, we began first with the evaluation of the jumps, then we collected the speed of the fist blows and, finally, we asked them to answer a series of questions ( *wellness*questionnaire) about their physical condition. The evaluations began 5 weeks before the competition, and were carried out for a total of 4 weeks, thus completing 12 monitoring sessions. The last week prior to the competition, it was not possible to continue with the monitoring, because the fighter had left for the country where the fight took place. Prior to each training session, the weight of the boxer was recorded, because the *software* used to evaluate the height of the jumps needed it to perform the relevant calculations, and also to know the variability of the weight during the training process. For this purpose, a Dolz balance, model DPP Industria Argentina, was used.

Regarding the plyometric assessment, using a Win Laborat jumping mat and Win Laborat software version 5.4 ©Fernando Di Nezza, the athlete was asked to perform 3 maximum attempts of 3 different types of jumps: jump with 3-4" arrest at 90° (SJ), jump with counter movement without arrest (CMJ) and jump by dropping forward from a standing position with one foot forward (DJ without height). After the completion of all the attempts, the one in which the highest altitude was reached was recorded. The protocol was based on the Bosco test evaluation battery, which has been proposed as a reliable tool for the assessment of lower limb explosive strength (Villa & García-López, 2003).

Hykso Punch Trackers © Hykso punch sensors were used to determine the speed of the punches. First, the boxer was asked to throw a punch with the left and after a 2-3" pause to throw a punch with the right; this was done 3 times and the highest velocities were recorded for each arm. With respect to the 5" strokes, it was evaluated only once and the average peak velocity of all the left and right strokes thrown separately during that time was recorded. Due to the relationship between the velocity achieved by the fists and the force applied in the punch by the fighters (Mack et al., 2010)these values could be established as a reference of the neuromuscular performance in the specific gestures of the upper body.

Finally, the athlete was asked to rate on a scale of 1 to 7 (Table 2) the level of perception regarding sleep quality, stress level, fatigue and muscle pain (Hooper et al., 1995).

Table 2

*Wellness questionnaire rating scale*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Dream** | Excellent | Very Good | Good | Regular | Malo | Very bad | Lousy |
| **Fatigue, Stress, DM** | Very very low | Very low | Bass | Regular | Tall | Very High | Very very high |

*Note:* DM - Muscle Pain.

On the other hand, it is important to highlight that a plyometric and stroke speed profile was established from the values obtained in the tests prior to starting the complete training cycle composed by the ATR periodization. In this way, the initial reference values were recorded, with which the fatigue monitoring results would later be compared.

## Results

### *Plyometric Profile*

Table 3 shows the height values achieved by the boxer for the Squat Jump (SJ), Counter Movement Jump (CMJ) and Drop Jump without height (DJ), evaluated before starting the training cycle.

Table 3

*Height achieved in jumping tests*

| EXERCISE | HEIGHT (cm) |
|---|---|
| SJ | 25.9 |
| CMJ | 27.2 |
| DJ (no height) | 28.4 |

*Note:* SJ - Squat Jump, CMJ - Counter Movement Jump, DJ - Drop Jump.

### *Stroke velocity profile*

Table 4 consists of the peak velocity values reached by straight punches (jab and direct) thrown into the air individually and for 5" without stopping, prior to the start of the training cycle.

Table 4

*Peak velocity achieved in straight fist strikes*

| EXERCISE | ARM | PEAK SPEED (m/s) |
|---|---|---|
| ISOLATED KNOCKS | Left | 4.4 |
| | Law | 5.0 |
| HITS IN 5" | Left | 7.5 |
| | Law | 7.8 |

*Note:* in the strokes launched during 5" is expressed as the average of the peak velocity reached by all the strokes executed.

### *Fatigue monitoring*

*Jumpability*

Table 5 and Figure 1 present the results of the jumping tests evaluated during the 4 weeks of monitoring. Only the values of the highest height reached among the three maximum SJ, CMJ and DJ attempts were recorded.

Table 5

*Height of jumps during fatigue monitoring*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SJ | 25.5 | 25.1 | 26.6 | 27.6 | 26.2 | 25.1 | 28.0 | 26.6 | 24.3 | 28.1 | 26.2 | 29.2 |
| CMJ | 25.4 | 25.4 | 26.2 | 28.1 | 26.5 | 26.5 | 27.6 | 27.8 | 26.9 | 29.0 | 26.6 | 28.4 |
| DJ | 27.2 | 25.7 | 28.1 | 29.0 | 25.9 | 27.1 | 28.5 | 27.1 | 27.0 | 30.0 | 28.4 | 29.1 |

*Note:* the height of the jumps is expressed in centimeters (cm). SJ - Squat Jump, CMJ - Counter Movement Jump, DJ - Drop Jump, DE - Standard Deviation

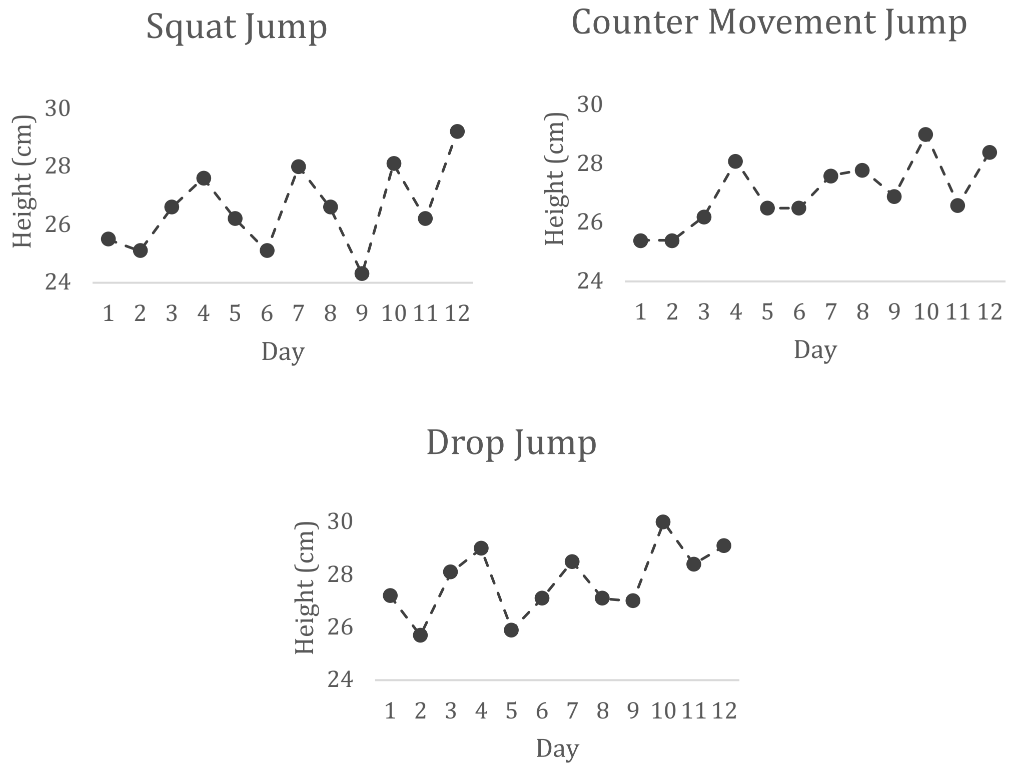


*Figure 1*. Height of the jumps.

Table 6 consists of the jump efficiency indices, percentage that was calculated based on the jump height obtained in the evaluations prior to the beginning of the fatigue monitoring period (Table 3).

Table 6

*Jump efficiency index*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SJ** | 98.5 | 96.9 | 102.7 | 106.6 | 101.2 | 96.9 | 108.1 | 102.7 | 93.8 | 108.5 | 101.2 | 112.7 |
| **CMJ** | 93.4 | 93.4 | 96.3 | 103.3 | 97.4 | 97.4 | 101.5 | 102.2 | 98.9 | 106.6 | 97.8 | 104.4 |
| **DJ** | 95.8 | 90.5 | 98.9 | 102.1 | 91.2 | 95.4 | 100.4 | 95.4 | 95.1 | 105.6 | 100.0 | 102.5 |

*Note:* the efficiency index is expressed as a percentage (%). SJ - Squat Jump, CMJ - Counter Movement Jump, DJ - Drop Jump.

Plyometric assessment during the monitoring process provided results below those initially obtained in the SJ on days 1, 2, 6, 9, in the CMJ on days 1, 2, 3, 5, 6, 9, 11, and in the DJ on days 1, 2, 3, 5, 6, 6, 8, 9. On days 4, 7, 10 and 12, efficiency rates higher than the initial ones were obtained for all jumps

*Stroke speed*

Table 7 and Figure 2 present the results of the stroke velocity tests obtained during the 4 weeks of fatigue monitoring. For the isolated strokes, the values of the highest velocity achieved among the three attempts made with each arm were recorded.

Table 7

*Stroke rate during fatigue monitoring*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ISOLATED KNOCKS** | Left | 4.8 | 4.2 | 5.4 | 5.0 | 4.4 | 4.6 | 4.6 | 4.9 | 4.3 | 4.4 | 5.0 | 5.0 |
| | Right | 5.7 | 4.8 | 5.8 | 5.7 | 5.4 | 6.1 | 5.8 | 6.3 | 5.5 | 5.6 | 5.4 | 4.9 |
| **HITS IN 5"** | Left | 7.9 | 7.2 | 7.9 | 7.9 | 4.6 | 6.9 | 7.6 | 7.8 | 5.3 | 6.4 | 3.9 | 6.3 |
| | Right | 7.7 | 6.7 | 7.5 | 7.3 | 4.4 | 6.8 | 6.5 | 7.3 | 5 | 6 | 3.8 | 5.9 |

*Note:* the speed is expressed in meters per second (m/s). Left - Left, Right - Right.

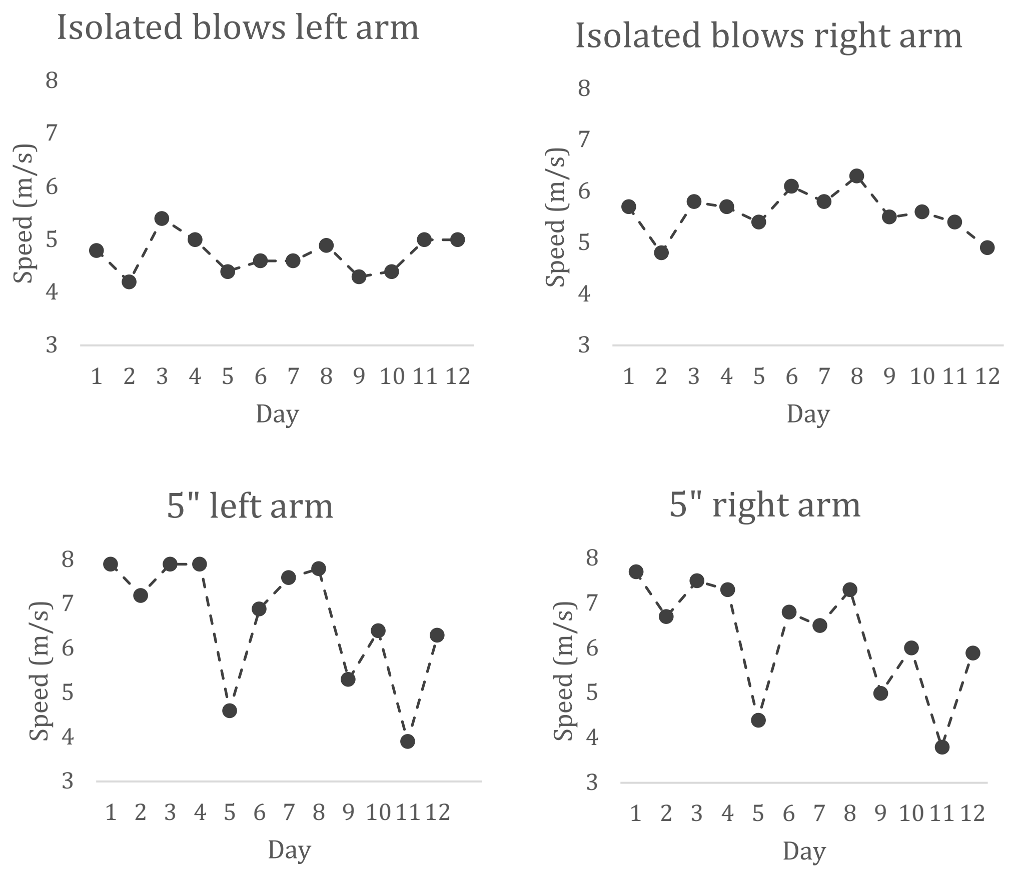


*Figure 2*. Speed of the blows.

Table 8 presents the efficiency indexes of the speed achieved in the different stroke protocols, with respect to the speed achieved in the initial evaluations (Table 4).

Table 8

*Stroke efficiency index*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ISOLATED KNOCKS** | Left | 109.1 | 95.5 | 122.7 | 113.6 | 100.0 | 104.5 | 104.5 | 111.4 | 97.7 | 100.0 | 113.6 | 113.6 |
| | Right | 114.0 | 96.0 | 116.0 | 114.0 | 108.0 | 122.0 | 116.0 | 126.0 | 110.0 | 112.0 | 108.0 | 98.0 |
| **HITS IN 5"** | Left | 105.3 | 96.0 | 105.3 | 105.3 | 61.3 | 92.0 | 101.3 | 104.0 | 70.7 | 85.3 | 52.0 | 84.0 |
| | Right | 98.7 | 85.9 | 96.2 | 93.6 | 56.4 | 87.2 | 83.3 | 93.6 | 64.1 | 76.9 | 48.7 | 75.6 |

*Note:* the efficiency index is expressed as a percentage (%). Left - Left, Right - Right, DE - standard deviation.

The evaluation of straight punch speed showed an improvement in almost all sessions for isolated punch speed, except for days 2 and 9 for the left punch, 2 and 12 for the right punch.

The 5" strokes presented lower efficiency rates when compared to pre-monitoring values, in the left arm on days 2, 5, 6, 9, 9, 10, 11, 12, and in the right arm in all sessions.

*Wellness Questionnaire*

Table 9 and Figure 3 show the results of the *wellness* questionnaire questions (sleep, stress, fatigue and muscle pain) during the course of fatigue monitoring.

Table 9

*Results of the Wellness questionnaire*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Dream** | 4 | 4 | 3 | 6 | 5 | 4 | 5 | 4 | 4 | 3 | 3 | 4 |
| **Stress** | 6 | 3 | 1 | 5 | 1 | 2 | 3 | 4 | 3 | 1 | 2 | 3 |
| **Fatigue** | 3 | 4 | 2 | 1 | 6 | 4 | 2 | 3 | 3 | 2 | 4 | 5 |
| **DM** | 1 | 6 | 2 | 1 | 4 | 7 | 2 | 1 | 7 | 4 | 7 | 4 |

*Note:* DM - Muscle pain.

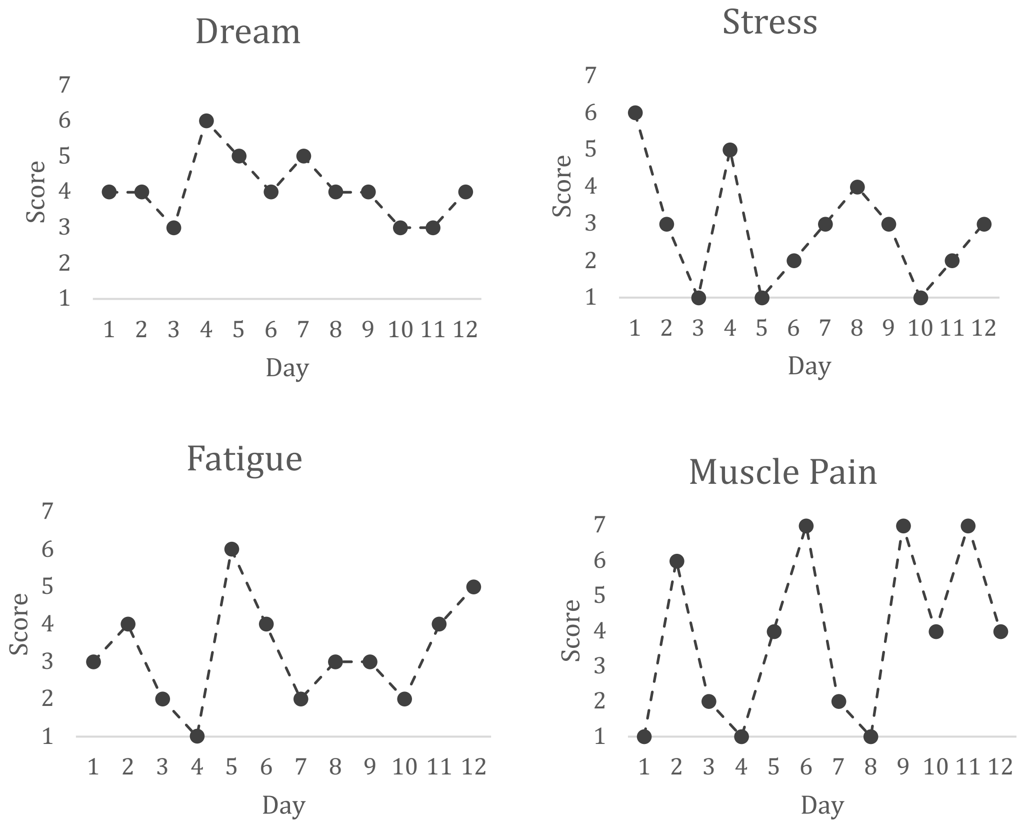


*Figure 3*. Scores of the different items of the *wellness*questionnaire.

Results between 4 (fair) and 7 (very poor-very high) were obtained for sleep quality on days 1, 2, 4, 5, 6, 7, 8, 9, and 12, stress level 1, 4 and 8, fatigue level 2, 5, 6, 11 and 12, muscle pain 2, 5, 6, 9, 10, 11 and 12.

*Relationship between fatigue monitoring evaluations*

Table 10 shows the relationship established between the results of the jumping and stroke speed evaluations, together with the scores of the *wellness*questionnaire. Fatigue was only considered in each indicator for all those cases in which the efficiency index was below 100% in terms of jumping and stroke speed, and when the questionnaire scores were between 4 and 7 (fair to very bad/very high).

Table 10

*List of fatigue indicators*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SJ** | * | * | | | | * | | | * | | | |
| **CMJ** | * | * | * | | * | * | | | * | | * | |
| **DJ** | * | * | * | | * | * | | * | * | | | |
| **Left A** | | * | | | | | | | * | | | |
| **Right A** | | * | | | | | | | | | | * |
| **Left 5"** | | * | | | * | * | | | * | * | * | * |
| **Right A** | * | * | * | * | * | * | * | * | * | * | * | * |
| **Dream** | * | * | | * | * | * | * | * | * | | | * |
| **Stress** | * | | | * | | | | * | | | | |
| **Fatigue** | | * | | | * | * | | | | | * | * |
| **DM** | | * | | | * | * | | | * | * | * | * |
| **TOTAL** | 6 | 10 | 3 | 3 | 7 | 8 | 2 | 4 | 8 | 3 | 5 | 6 |

*Note:* SJ - Squat Jump, CMJ - Counter Movement Jump, DJ - Drop Jump, Left A - Isolated left arm strikes, Right A - Isolated right arm strikes, Left 5" - Left arm strikes for 5", Right 5" - Right arm strikes for 5", DM - Muscle soreness.

Figure 4 shows the daily variation of the totals of the ratio of fatigue indicators in Table 10, as well as the weekly variation calculated by the sum of the scores obtained in the 3 sessions of each one.

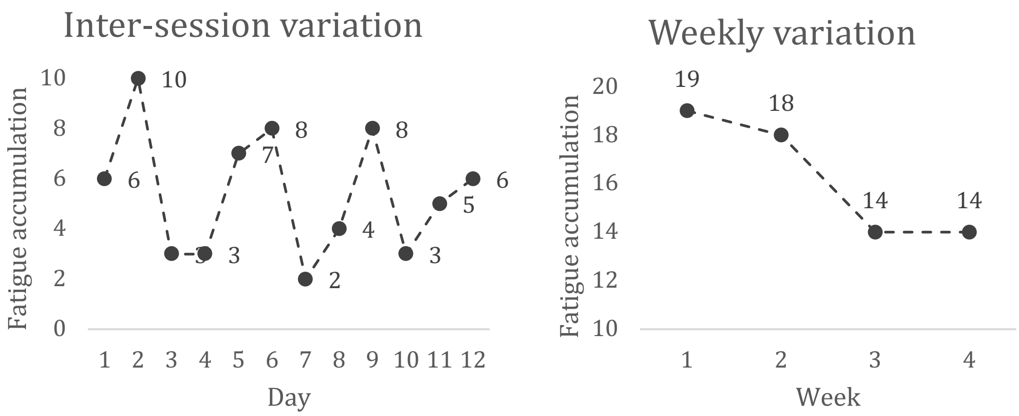


*Figure 4*. Daily and weekly variation of the totals of the comparative fatigue indicators.

Table 10 and Figure 4 show 3 peaks of fatigue accumulation with scores of 10 and 8 on days 2, 6 and 9, followed by another of the highest values with a score of 7 on day 5. The weekly variation represented in Figure 4, which expresses the sum of the scores achieved in the 3 sessions of each week, shows a gradual decrease in the accumulation of fatigue between weeks 1 and 3, with a maintenance between weeks 3 and 4.

*Body weight*

Table 11 and Figure 5 show the boxer's body weight records, evaluated prior to the beginning of each strength training session. The distance to the competition category in kilograms (kg) and percentage (%) is also presented.

Table 11

*Body weight and relation to competition category*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight (Kg)** | | 63 | 62.8 | 62.6 | 62.3 | 63.1 | 62.6 | 63.8 | 62.6 | 63.3 | 62.7 | 63.3 | 63.3 |
| **Distance to category** | Kg | 1.8 | 1.6 | 1.4 | 1.1 | 1.9 | 1.4 | 2.6 | 1.4 | 2.1 | 1.5 | 2.1 | 2.1 |
| | % | 2.9 | 2.6 | 2.3 | 1.8 | 3.1 | 2.3 | 4.2 | 2.3 | 3.4 | 2.5 | 3.4 | 3.4 |

*Note:* the distance to the light category was calculated based on the highest limit of the same(61.2 kg).

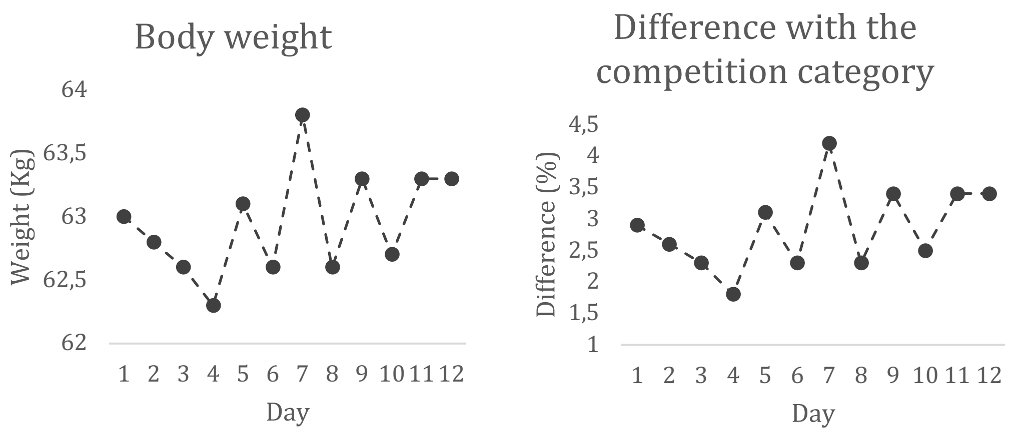


*Figure 5*. Body weight and percentage difference with the competition category.

Table 12 shows the inter-session weight difference, represented in kilograms and as a percentage in relation to the weight recorded on the previous evaluation day.

Table 12

*Inter-session weight variation*

| | 1-2 | 2-3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | 8-9 | 9-10 | 10-11 | 11-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight change (Kg)** | -0.2 | -0.2 | -0.3 | 0.8 | -0.5 | 1.2 | -1.2 | 0.7 | -0.6 | 0.6 | 0 |
| **Percentage of weight change (%)** | -0.3 | -0.3 | -0.5 | 1.3 | -0.8 | 1.9 | -1.9 | 1.1 | -1 | 1 | 0 |

Body weight records showed a maximum inter-session decrease of 1.9% between days 7-8 and a minimum of 0.3% between days 1-2 and 2-3. The lowest weight during the fatigue monitoring process was found on day 4 (62.3 kg), being 1.8% of the competition category. The highest weight was recorded on day 7 (63.8 kg), being 4.2% of the competition category. Between the first day on which the athlete was weighed and the last day, there was a 0.5% increase in body weight.

## Discussion

The main objective of this work was to analyze the fatigue monitoring process of a professional female boxer, in the search to maximize the positive effects of training loads and minimize the negative ones (Gabbett et al., 2017).

During the fatigue monitoring process, body weight was not taken into account as a factor that would have impacted the athlete's fatigue, considering that <3% weight adjustment would not generate negative effects on performance (Barley et al., 2019; Burke et al., 2021) and that in the case presented the maximum weight loss was 1.9% of body weight.

With regard to jumping, while some studies have used as a control measure only CMJ (Gathercole et al., 2015; Kennedy & Drake, 2017), other types of jumps have also been recommended and used for the assessment of fatigue and/or neuromuscular performance (Coutts et al., 2007; Halson, 2014; Rezzonico, 2022). It is for this same reason that in the present study we chose to evaluate the SJ and DJ, in conjunction with the CMJ, in order to know the Strength-Power performance of the lower limbs during the monitoring process.

Specific gestures have also been used to investigate athlete performance (Chaabène et al., 2015; Coutts et al., 2007; Halson, 2014; Mack et al., 2010). Taking this into account, the velocity of straight fist strikes was used as a measure of specific performance of boxing gestures (Kimm & Thiel, 2015). Thus, we chose to evaluate the velocity of isolated straight blows, and also of continuous blows in 5" due to the contribution of a double peak of force when launching combinations of these (McGill et al., 2010).

Considering that several studies have made use of questions about athletes' perceptions of their performance levels (Hamlin et al., 2019; Ramirez-Lopez et al., 2022; Thorpe et al., 2017)the ones used in the work of Hooper et al. were selected. (1995) and thus formed the *wellness* questionnaire for the subjective assessment of fatigue.

During the boxer's Strength-Power training process, in those cases in which an accumulation ≥6 points was found in the ratio of fatigue indicators, it was chosen to schedule a 10% decrease in the volume of the training load for that day. In this way, the monitoring allowed a rearrangement of the workloads during the fine-tuning period, which promoted a decrease in the sum of the weekly fatigue indicators. This would be favorable to reach peak performance (le Meur et al., 2012) and prevent the occurrence of injury or any disease that could interfere with participation in competition (Drew & Finch, 2016).

Although the comparison between the initial values of the performance profiles and the last monitoring record (day 12) showed an increase in the height for all jumps and the speed of the isolated straight punches, but a decrease in the speed of the rest of the punches, it should be noted that during the last week the boxer reported pain in her right shoulder after a *sparring* session that took place between evaluations 10-11. For this reason, during sessions 11 and 12 a greater unloading of the upper body exercises was carried out, as well as the last *sparring*sessions were cancelled.

The lack of evidence on an efficient system for monitoring the fatigue of the fighters during their pre-competitive training, which allows reaching the objectives with the least possible compromise of performance, would make this work the starting point to investigate with a greater number of participants, men and women of different weight categories, and in different competitive scenarios, in order to establish a reliable method of control.

Although the fact of having analyzed a single case represents a limitation to conclude about the use of fatigue monitoring during the period of boxers' training, in the same way and considering this work, coaches could make use of some of the variables that were used for the control of their athletes.

## Conclusions

Through this research, the results of the fatigue monitoring process have been investigated in a professional boxer with 9 years of experience in the rental field and in Strength-Power training, while she was preparing for a fight for the WBC, WBA, IBF and WBO world titles in the lightweight category.

The fatigue monitoring process consisted of 3 weekly evaluations on Monday, Wednesday and Friday prior to the start of their Strength-Power training, for 4 continuous weeks and carrying out the last evaluation 8 days before the fight. The performance indicators taken as reference were the height of the jumps (SJ, CMJ and DJ without height), speed of the straight punches (isolated and continuous in 5") and a *wellness* questionnaire consisting of 4 questions: quality of sleep, stress level, degree of fatigue and muscle pain. The variation of their body weight prior to each training session was also recorded, in order to know the distance with the competition category as the combat approached and if it was necessary to make an adjustment to it.

The results of the research demonstrated a variation in the boxer's fatigue levels throughout the process of tuning up for her bout. A comparison between the different indicators evaluated showed a gradual reduction in fatigue during the first 3 weeks, and a maintenance of fatigue between weeks 3-4. An improvement in height attained was evident for all jumps (SJ +12.7%, CMJ +4.4%, DJ +2.5%) and for isolated left straight strokes (+13.6%) when comparing the initial baseline values of the plyometric and stroke velocity profiles with the latter obtained during fatigue monitoring. On the contrary, a reduction was found in the velocity of isolated blows launched with the right arm (-2%) and of continuous blows in 5" for both arms (left -16% and right -24.4%).

## References

Barley, O. R., Chapman, D. W., & Abbiss, C. R. (2019). The Current State of Weight-Cutting in Combat Sports. *Sports (Basel, Switzerland), 7*(5). https://doi.org/10.3390/SPORTS7050123

Burke, L. M., Slater, G. J., Matthews, J. J., Langan-Evans, C., & Horswill, C. A. (2021). ACSM Expert Consensus Statement on Weight Loss in Weight-Category Sports.

*Current Sports Medicine Reports, 20*(4), 199–217. https://doi.org/10.1249/JSR.0000000000000831

Chaabène, H., Tabben, M., Mkaouer, B., Franchini, E., Negra, Y., Hammami, M., Amara, S., Chaabène, R. B., & Hachana, Y. (2015). Amateur Boxing: Physical and Physiological Attributes. *Sports Medicine, 45*(3), 337–352. https://doi.org/10.1007/S40279-014-0274-7

Chen, Y. S., Clemente, F. M., Pagaduan, J. C., Crowley-McHattan, Z. J., Lu, Y. X., Chien, C. H., Bezerra, P., Chiu, Y. W., & Kuo, C. D. (2022). Relationships between perceived measures of internal load and wellness status during overseas futsal training camps. *PloS One, 17*(4). https://doi.org/10.1371/JOURNAL.PONE.0267227

Coutts, A. J., Slattery, K. M., & Wallace, L. K. (2007). Practical tests for monitoring performance, fatigue and recovery in triathletes. *Journal of Science and Medicine in Sport, 10*(6), 372–381. https://doi.org/10.1016/J.JSAMS.2007.02.007

Drew, M. K., & Finch, C. F. (2016). The Relationship Between Training Load and Injury, Illness and Soreness: A Systematic and Literature Review. *Sports Medicine, 46*(6), 861–883. https://doi.org/10.1007/S40279-015-0459-8

Gabbett, T. J., Nassis, G. P., Oetter, E., Pretorius, J., Johnston, N., Medina, D., Rodas, G., Myslinski, T., Howells, D., Beard, A., & Ryan, A. (2017). The athlete monitoring cycle: a practical guide to interpreting and applying training monitoring data. British *Journal of Sports Medicine, 51*(20), 1451–1452. https://doi.org/10.1136/BJSPORTS-2016-097298

Gathercole, R. J., Stellingwerff, T., & Sporer, B. C. (2015). Effect of acute fatigue and training adaptation on countermovement jump performance in elite snowboard cross athletes. *Journal of Strength and Conditioning Research, 29*(1), 37–46. https://doi.org/10.1519/JSC.0000000000000622

Halson, S. L. (2014). Monitoring training load to understand fatigue in athletes. *Sports Medicine (Auckland, N.Z.), 44*(Suppl 2), 139–147. https://doi.org/10.1007/S40279-014-0253-Z

Hamlin, M. J., Wilkes, D., Elliot, C. A., Lizamore, C. A., & Kathiravel, Y. (2019). Monitoring training loads and perceived stress in young elite university athletes. Frontiers in Physiology, 10(JAN). https://doi.org/10.3389/FPHYS.2019.00034

Hooper, S. L., Mackinnon, L. T., Howard, A., Gordon, R. D., & Bachmann, A. W. (1995). Markers for monitoring overtraining and recovery. *Medicine and science in sports and exercise, 27*(1), 106–112.

Kennedy, R. A., & Drake, D. (2017). The effect of acute fatigue on countermovement jump performance in rugby union players during preseason. *The Journal of Sports Medicine and Physical Fitness, 57*(10), 1261–1266. https://doi.org/10.23736/S0022-4707.17.06848-7

Kimm, D., & Thiel, D. v. (2015). Hand speed measurements in boxing. *Procedia Engineering, 112*, 502–506. https://doi.org/10.1016/J.PROENG.2015.07.232

le Meur, Y., Hausswirth, C., & Mujika, I. (2012). Tapering for competition: A review. Science & Sports, 27(2), 77–87. https://doi.org/10.1016/J.SCISPO.2011.06.013

Lenetsky, S., Harris, N., & Brughelli, M. (2013). Assessment and contributors of punching forces in combat sports athletes: Implications for strength and conditioning. *Strength and Conditioning Journal, 35*(2), 1–7. https://doi.org/10.1519/SSC.0B013E31828B6C12

Mack, J., Stojsih, S., Sherman, D., Dau, N., & Bir, C. (2010). Amateur Boxer Biomechanics and Punch Force. *ISBS - Conference Proceedings Archive*. https://ojs.ub.uni-konstanz.de/cpa/article/view/4491

McGill, S. M., Chaimberg, J. D., Frost, D. M., & Fenwick, C. M. J. (2010). Evidence of a Double Peak in Muscle Activation to Enhance Strike Speed and Force: An Example With Elite Mixed Martial Arts Fighters. *Journal of Strength and Conditioning Research, 24*(2), 348–357. https://doi.org/10.1519/JSC.0B013E3181CC23D5

Mukhopadhyay, K. (2021). Physiological basis of adaptation through super-compensation for better sporting result. *Advances in Health and Exercise, 1*(2), 30–42. https://www.turkishkinesiology.com/index.php/ahe/article/view/13

Pallarés, J. G., Martínez-Abellán, A., López-Gullón, J. M., Morán-Navarro, R., de la Cruz-Sánchez, E., & Mora-Rodríguez, R. (2016). Muscle contraction velocity, strength and power output changes following different degrees of hypohydration in competitive olympic combat sports. *Journal of the International Society of Sports Nutrition, 13*(1). https://doi.org/10.1186/S12970-016-0121-3

Ramírez-López, C., Till, K., Weaving, D., Boyd, A., Peeters, A., Beasley, G., Bradley, S., Giuliano, P., Venables, C., & Jones, B. (2022). Does perceived wellness influence technical-tactical match performance? A study in youth international rugby using partial least squares correlation analysis. *European Journal of Sport Science, 22*(7), 1085–1093. https://doi.org/10.1080/17461391.2021.1936195

Rezzonico, G. (2022). *Entrenamiento de la Fuerza en el Boxeo: construyendo el knockout*. Autoedición.

Thorpe, R. T., Atkinson, G., Drust, B., & Gregson, W. (2017). Monitoring Fatigue Status in Elite Team-Sport Athletes: Implications for Practice. *International Journal of Sports Physiology and Performance, 12*(Suppl 2), 27–34. https://doi.org/10.1123/IJSPP.2016-0434

Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2016). Tracking morning fatigue status across in-season training weeks in elite soccer players. International Journal of Sports Physiology and Performance, 11(7), 947–952. https://doi.org/10.1123/IJSPP.2015-0490

Villa, J. G., & García-López, J. (2003). Tests de salto vertical (I): Aspectos funcionales. *RendimientoDeportivo*, 1–14. https://www.researchgate.net/publication/301960181_Tests_de_salto_vertical_I_Aspectos_funcionales

Wada, N., Ito, K., & Nakagawa, T. (2020). Optimal training plans on physical performance considering supercompensation. *Communications in Statistics – Theory and Methods, 49*(15), 3761–3771. https://doi.org/10.1080/03610926.2020.1722845

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