Research and analysis of an exercise internal load system based on a big data context assessment

Chengjie Ye[1a] , Xinna Li[2b] , Jingwei Li[3c] , Jiachi Ye[4d] , Binghong Gao [5e*]

[1]School of Athletic Performance, Shanghai University of Sport, Shanghai 200438, China
[2]China Table Tennis College, Shanghai University of Sport, Shanghai 200438, China
[3]ByteDance, Beijing 100098, China
[4]School of Athletic Performance, Shanghai University of Sport, Shanghai 200438, China
Nanjing Sport Institute, Nanjing 210014, Jiangsu, China
[5]School of Athletic Performance, Shanghai University of Sport, Shanghai 200438, China

[a]2121111019@sus.edu.cn , [b]lixinnal@126.com ,
[c]525020422@qq.com , [d]yejiachi@nsi.edu.cn ,
*[e] Corresponding author: gaobinghong@126.com

Abstract. Objectives: To examine how Rating of Perceived Exertion (RPE) and session RPE (sRPE) are used in Olympic combat sports. Along with the quantification of training and competition load, the application effect is explored from the perspectives of reliability and validity. Methods: Search databases in recent 10 years like Pubmed, Web of Science, and Google Scholar were consulted, and 28 categories of literature were finally included. Results: 1) Only judo competitions (ICC=0.84, 95%CI:0.11-1.00) demonstrate good reliability. 2) Overall, a good level of criteria validity was seen (r=0.44-0.92, 95%CI:0.15-0.95). The key variables determining validity were the sport, playing level, specific activities, cognitive level, training phase, and RPE collection time. 3) The criterion validity is positively correlated with both playing level and cognitive level. The validity for striking combat sports is superior to that for grappling combat sports, and the validity for the pre-competition phase is superior to that for the competition phase. RPE taken 30 minutes after training is more valid than RPE collected right away. Conclusion: The RPE and sRPE show good validity, although further research is required to assess its reliability. Combining internal and external load indicators to improve the systematicness of internal load monitoring in combat sports is necessary.

Keywords: training load; match load; load monitoring; load quantification

1 Introduction

In the modern Olympic Games, combat sports such as boxing, taekwondo, wrestling, judo, and karate (the new sport in the 2020 Tokyo Olympic Games) compete by employing specific methods like striking and grappling [1-2]. Traditional load

G. Guan et al. (eds.), *Proceedings of the 2023 3rd International Conference on Education, Information Management and Service Science (EIMSS 2023)*, Atlantis Highlights in Computer Sciences 16,
https://doi.org/10.2991/978-94-6463-264-4_48

monitoring techniques are extremely confrontational, and they frequently result in sports injuries, equipment damage, and wound infections. The total amount of stimulation that an athlete's psychological and physiological systems experience while training or in non-training circumstances is known as an internal load [3-4], and the value of heart rate (HR) and blood lactic acid (BLA) is the most commonly used technique to measure and evaluate internal load in combat sports [5-7]. However, some research has shown that resistance training, high-intensity training, and intermittent training all exhibit non-linear relationships between HR and sport intensity [8]. Athletes who have their blood drawn frequently run a higher risk of developing wound infections, and it costs money and effort to measure things like speed and power. The approach of a thorough evaluation of internal load by subjective and objective indicators has attracted the attention of researchers in recent years since traditional load monitoring indicators are not easily used in the training practice of combat sports. The main problem that needs to be solved in such investigations is particularly the validity and reliability of subjective evaluation.

Internal load evaluation based on the Rating of Perceived Exertion (RPE) consists of an RPE scale and session-RPE (sRPE) [9-10]. Researchers started combining RPE and sRPE with conventional load monitoring theories to estimate internal load intensity by RPE scale and internal load volume by sRPE due to the numerous objectivity limits of RPE and sRPE. RPE has the benefit of being simple, quick, and free to measure athletes' internal loads from both a physiological and psychological perspective. According to research by Lovell et al, RPE is a more accurate measure of load intensity in rugby wrestling training than HR and GPS-based indices. However, RPE successfully combines the benefits of RPE and Training Impulse (TRIMP), and it has a very broad range of applications because it considers both the external load provided by coaches and the internal load experienced by athletes [3]. The reliability and validity research of the internal load monitoring based on RPE is a prerequisite for its systematic application in combat sports and is the key to improving the load evaluation system of combat sports. This study will analyze and summarize the existing research results and progress by reviewing the literature on the reliability and validity of RPE for evaluating the internal load of Olympic combat sports from 2012 to 2022.

2 METHODS

2.1 Search Strategy

Searches for all published works were conducted in English-language databases such as Pubmed, Web of Science (WOS), and Google Scholar. The PRISMA statement served as the basis for conducting the systematic review. Combat sports and RPE were utilized as relevant subject terms in the search, and Boolean operators were used to creating links between the results. The search terms included: combat sport, boxing, taekwondo, karate, judo, wrestling, rating of perceived exertion, session rating of perceived exertion, competition training, physiological responses, blood lactate, heart rate, and training impulse.

2.2 Inclusion and Exclusion Criteria

After a search, the titles, abstracts, and full texts of the literature were checked; those that met the following requirements were then included in the study: 1) Participants in the study were athletes competing in Olympic combat sports; 2) RPE or sRPE load estimation and evaluation during training or competition; 3) Original studies published in English between January 1, 2012, and December 31, 2022, in peer-reviewed publications. For this investigation, the following exclusion criteria were applied: 1) no full-text available; 2) only reviews, abstracts, or conference articles; 3) The goal was to assess the effects of sports supplements; 4) it had to do with recovery and rehabilitation procedures.

2.3 Risk of Bias and Quality Assessment

According to the STROBE statement, the risk of bias and study quality were evaluated in this study. The assessment was set up based on previous research and consisted of six items: subject selection, study design, RPE or sRPE measurement, study results, variable control, and data analysis. Each item was given a score of "1" if it had a clear description in the literature and a score of "0" if it was unavailable or unclear. The final quality rating score of the included literature was calculated using the sum of the values of the six items. Studies rated "0-2" as being of low quality, "3-4" as being of moderate quality, and "5-6" as being of high quality.

2.4 Data Extraction

The basic study information (authors, publication date), study subjects (sport, number, age, playing level), load indicators (RPE, sRPE, HR, BLA, TRIMP), training science indicators (type of specific activities, sport intensity and volume, training method, time of duration), and reliability and validity indicators were all taken from the included literature.

3 RESULTS

3.1 Study Selection

The literature search, screening, and inclusion process is shown in Figure 1. 320 English-language periodicals were obtained after duplicates of a total of 417 various types of literature were eliminated. Title and abstract screening removed 243 different categories of literature; the remaining 77 were then subjected to additional inclusion and exclusion criteria; 49 papers were ultimately reduced, leaving 28 studies that satisfied the screening requirements and were all included in this study.

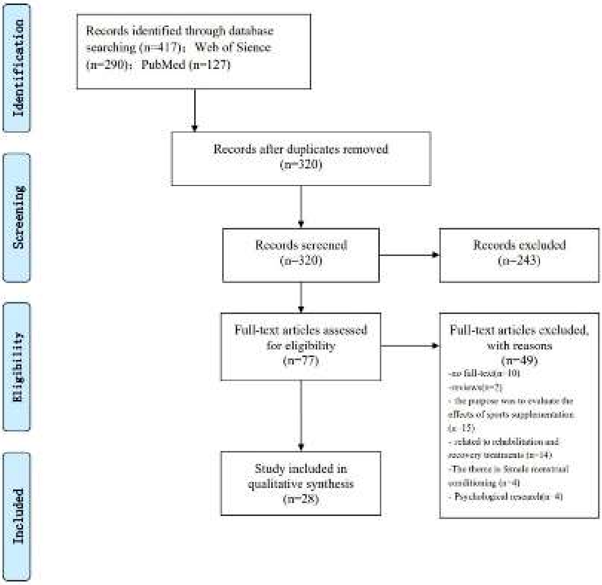

Fig. 1. Literature search strategy

4 DISCUSSION

4.1 Reliability

The relevant investigations have all indicated that RPE-based load measurements are generally reliable across a range of sports and training modalities (ICC=0.55-0.95, 95% CI:0.11-1.00). Moderate reliability was reported for intermittent training and fencing (ICC=0.55-0.73, 95% CI: 0.53-0.83). Higher reliability was found by basketball, resistance training, and constant-load training (ICC=0.78-0.95, 95% CI:0.70-0.97), which contrasts with the poor reliability of RPE and sRPE in assessing intermittent sport. The reason for this is that while high-intensity intermittent sports like fencing cause athletes to subjectively prefer the level of effort at the moment before the end of the exercise, which results in a bias in reliability, continuous running in basketball and continuous force in judo make the athletes more clear about their subjective level of effort. With only judo included in the study showing the reliability of utilizing RPE and sRPE to assess competition load, there are currently few studies on the reliability of RPE and sRPE in combat sports. Further investigation of reliability on RPE in estimating the internal load of these two types of combat sports is important because they both involve high-intensity intermittent striking and high-intensity continuous grappling activities.

5 Basic theory of attitude solving

5.1 Basic theory of attitude solving

The essence of the attitude solution is to solve for the orientation between the coordinate systems by means of a coordinate transformation, which is described by a rotation matrix that is continuously updated during the transformation process to solve for the attitude.

Establishment of common coordinate systems.

When describing the attitude of an object, the spatial coordinate system is usually used as a reference frame. The main spatial coordinate systems involved in attitude resolution are: the navigation coordinate system (n-system), and the carrier coordinate system (b-system).

(1) Navigation coordinate system (n-system): $S_n(O_n, X_n, Y_n, Z_n)$

The navigation coordinate system is the coordinate system used to transform the behavior of the change of attitude of the moving vehicle. X_n, Y_n, Z_n.

(2) Carrier coordinate system (b-series): $S_b(O_b, X_b, Y_b, Z_b)$

A carrier coordinate system is generally a follower coordinate system built on top of a carrier and is not uniquely defined. The subject has the centre of mass of the carrier as the origin of the b-series, X_b, Y_b, Z_b pointing to the right, in front and above the carrier respectively.

Attitude angle and rotation matrix.

The attitude angle is used to characterise the orientation of the b-system with respect to the n-system, while the process of coordinate transformation between the b-system and the n-system can be described using a rotation matrix.

(1) Stance angle

Based on the established b- and n-systems, the attitude angle is defined as: cross-roll angle ($\emptyset$),Indicates the angle between X_b and $X_n O_n Y_n$ when the carrier is rotated around the Y_b axis, positive counterclockwise and ranging from -180° to 180°; Pitch angle (θ), indicating the angle between axis X_b and $O_n X_n Y_n$ as the carrier rotates around axis Y_b, positive counterclockwise and ranging from -90° to 90°; Heading angle (Ψ), indicating the angle between the projection of the carrier X_b axis on the horizontal plane of the earth and the geomagnetic north pole as the carrier rotates around axis Z_b, is positive counterclockwise and ranges from -180° to 180°.

(2) Rotation matrix

In three-dimensional space, any orientation in which the b-series is located can be achieved by three successive rotational transformations of the n-series to achieve coincidence.As show in figure 2.

where R(x) denotes the rotation matrix of the carrier rotated by x° about any coordinate axis; expanding the above equation:

$$C_n^b = \begin{bmatrix} cos\emptyset cos\Psi + sin\emptyset sin\theta sin\Psi & sin\emptyset sin\theta cos\Psi - cos\emptyset sin\Psi & -sin\emptyset cos\theta \\ sin\Psi cos\theta & cos\theta cos\Psi & sin\theta \\ sin\emptyset cos\Psi - cos\emptyset sin\theta sin\Psi & -sin\emptyset cos\Psi - sin\theta cos\emptyset cos\Psi & cos\emptyset cos\theta \end{bmatrix} \tag{1}$$

And the rotation matrices during the equivalent transformation of the b and n systems are all unitary orthogonal matrices, thus:

$$C_b^n = (C_n^b)^{-1} = (C_n^b)^T \tag{2}$$

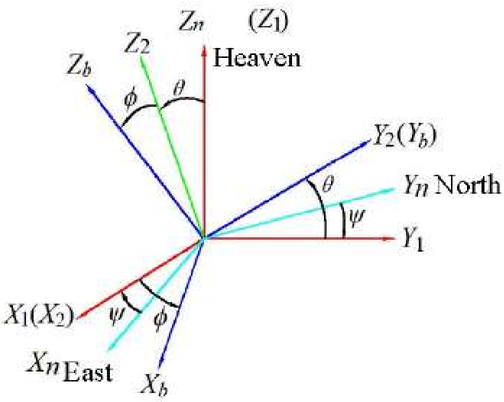

Fig. 2. Transformation relations between the b-series and the n-series

(3) Comparison and analysis of attitude update methods

The application scenario of the object (carrier) under test and the inherent nature of the method itself need to be taken into account during the pose matrix update. A comparison of the advantages and disadvantages of each update method is given below in Table 1.

Table 1. Comparison table of attitude update methods

Update method	Advantages	Disadvantages
Euler's angle method	Pose matrix strictly orthogonal, no further orthogonalisation required	Pitch angle degradation occurs around 90°
Quadratic Algorithm	Smaller calculations, good real time, good for full attitude operation	May accumulate errors and produce illegal quaternions

In summary, the two attitude update methods have their own advantages, but neither of them will have an impact on the accuracy of the solution.

5.2 Single sensor attitude solver

The inertial measurement unit is used to sense the carrier's orientation information with respect to the reference coordinate system and to obtain the carrier attitude by solving it. The principle of solving for different sensors in the measurement unit varies. In this paper, the sensors chosen for the subject are solved for attitude and the causes of the solving errors are analysed.

Gyroscope based attitude solving.

Theoretically, the attitude angle can be obtained by substituting the measured angular velocity of the gyroscope into the above attitude update method and solving for it. For example, the quaternion update method:

$$Q_{t+1} = Q_t + Q_{t+1}dt \tag{3}$$

The joint attitude rotation matrix equation gives the conversion equation between the quaternion and the attitude angle:

$$\begin{cases} \emptyset = \arctan\left(\frac{2(q_2q_3+q_0q_1)}{q_0^2-q_1^2-q_2^2-q_3^2}\right) \\ \theta = -\arcsin\left(-2(q_1q_3 - q_0q_2)\right) \\ \psi = \arctan\left(\frac{2(q_1q_2+q_0q_3)}{q_0^2-q_1^2-q_2^2-q_3^2}\right) \end{cases} \tag{4}$$

Accelerometer-based attitude solving.

The accelerometer senses the force in each axial direction as the object's attitude changes, thus obtaining the acceleration of gravity in that axis. When the n-system coincides with the b-system and the carrier is not subjected to external forces, the accelerometer output is $g_n = [0\ 0\ g]$ If the carrier is at rest or moving at constant speed, the accelerometer output is $a_b = [a_x, a_y, a_z]$. The conversion relationship between g_n, a_b is then:

$$a_b = C_n^b g_n \tag{5}$$

Jointly, if the accelerometer measurement is known, then:

$$\theta = sin^{-1}(-a_x/g) \tag{6}$$

$$\emptyset = tan^{-1}(a_y/gcos\theta) \tag{7}$$

Magnetometer-based attitude solving.

Magnetometers are magnetoresistive sensors that detect the strength of the geomagnetic field in an axial direction. If the magnetometer measurement $m_b = [m_x\ m_y\ m_z]^T$ under the b-system, then after two coordinate transformations, the b-system coincides with the Z-axis of the n-system, i.e:

$$\left[H_x\ H_y\ H_z\right]^T = C(\theta)C(\emptyset)m_b \tag{8}$$

Knowing that the projection of the Earth's magnetic field strength on the horizontal plane coincides with the north direction of the navigation coordinate system, the heading angle is expressed as:

$$\Psi = tan^{-1}(H_x/H_y) \quad 9$$

Comparative analysis of single sensor attitude resolution.

The error analysis based on the attitude solved by the three different sensors is summarised in Table 2 below.

Table 2. Analysis of sensor attitude solution results

Sensors	Advantages	Disadvantages
Gyroscope	Good dynamic performance with high short time accuracy	Drift errors accumulate over time, with large errors over long periods of time
Accelerometers	No accumulation of errors and good statics	Vulnerable to non-gravitational acceleration, poor dynamic performance
Magnetometers	No accumulation of errors, good dynamic and static properties	Vulnerable to magnetic interference

In summary, all attitudes solved by a single sensor are subject to error, but the causes of error vary from sensor to sensor. The manufacturing process is the main factor affecting the accuracy of a sensor's measurement. Therefore, in order to better fuse the information to solve the attitude, the next step is to model the attitude sensor error analysis and design the calibration method, and then use a reasonable method to fuse the multi-sensor information to improve the attitude measurement accuracy.

6 Conclusion

It is advised that researchers create wearable load monitoring systems that are lightweight, precise, and efficient in the future to get the relevant digital indicators without interrupting combat sports training and competition. RPE and sRPE in striking and grappling combat sports need to be further verified to expand the scope of their applications, but it's also important to optimize and improve the load monitoring system for combat sports by thoroughly connecting international frontier theories and domestic practical experience.

References

1. Bromley SJ, Drew MK, McIntosh A, et al. Rating of perceived exertion is a stable and appropriate measure of workload in judo. J Sci Med Sport 2018; 21:1008–1012

2. Xie Y, Geng HF, Li Z. An empirical study on training load evaluation method of racing sports based on SRPE. China Sport Sci Tec 2020; 56:30–38
3. Foster C, Florhaug JA, Franklin J, et al. A new approach to monitoring exercise training. J Strength Cond Res 2001; 15:109–115
4. Impellizzeri FM, Rampinini E, Marcora SM. Physiological assessment of aerobic training in soccer. Journal of Sports Sciences 2005; 23:583–592
5. Branco B, Massua LM, Andreato LV, et al. Association between the rating perceived exertion, heart rate and blood lactate in successive judo fights (randori). Asian J Sports Med 2013; 4:125–130
6. Serrano-Huete V, Latorre-Román P, García-Pinillos F, et al. Acute effect of a judo contest on muscular performance parameters and physiological response. Int J Kin Sports Sci 2016; 4:24-31
7. Tabben M, Sioud R, Haddad M, et al. Physiological and perceived exertion responses during international karate kumite competition. Asian J Sports Med 2013; 4:263-271
8. Yu HJ, Wang XX. The development of the session-rpe method for training load monitoring and usefulness in sports training. China Sport Sci 2021; 41:42–57
9. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982; 14:377-381
10. Yang GQ. China's winning advantages and experience enlightenment in preparing for the Tokyo Olympic Games—the preparation situation and strategy of the 2024 Paris Olympic Games. China Sport Sci 2021; 41:18–29