The Use of Session-RPE Method for Quantifying Training Load in Diving

Carlo Minganti, Laura Capranica, Romain Meeusen, and Maria Francesca Piacentini

Purpose: The aim of the present study was to assess the effectiveness of perceived exertion (session-RPE) in quantifying internal training load in divers. Methods: Six elite divers, three males (age, 25.7 ± 6.1 y; stature, 1.71 ± 0.06 m; body mass, 66.7 ± 1.2 kg) and three females (age, 25.3 ± 0.6 y; stature, 1.63 ± 0.05 m; body mass, 58.3 ± 4.0 kg) were monitored during six training sessions within a week, which included 1 m and 3 m springboard dives. The Edwards summated heart rate zone method was used as a reference measure; the session-RPE rating was obtained using the CR-10 Borg scale modified by Foster and the 100 mm visual analog scale (VAS). Results: Significant correlations were found between CR-10 and VAS session-RPE and the Edwards summated heart rate zone method for training sessions (r range: 0.71–0.96; R² range: 0.50–0.92; P < 0.01) and for divers (r range: 0.67–0.96; R² range: 0.44–0.92; P < 0.01). Conclusions: These findings suggest that session-RPE can be useful for monitoring internal training load in divers.

Keywords: rating of perceived exertion, heart rate, internal training load

Men’s and women’s diving includes individual springboard (1 and 3 m) and platform (5, 7.5, and 10 m) and synchronized springboard (3 m) and platform (10 m) events. Being a closed-skill sport, diving performances depend on coordination, technical complexity, and artistic presentation. Dives are assigned a degree of difficulty from 1.2 to 3.8 points, according to the tables of the Federation Internationale de Natation (2009), which take into consideration dive height (ie, 1, 3, 5, 7.5 and 10 m), starting position (ie, standing or hand-standing), direction of rotation (ie, forward, backward, reverse, inward, and twisting), number of half rotations around the transversal (somersaults) and the longitudinal (twists) axes, and fly position (ie, tuck, pike, straight, and free).
Elite divers train in excess of 20–30 hours per week. Two training sessions, lasting 2 h each, are generally carried out (one in the morning and one in the afternoon). The training sessions are held both in the pool and in the gym (dry-land training). The training in the pool may have different contents such as the implementation of the basic technical elements (ie, take off, come-out, line up and entries), and of the basic dives (Voluntaries) as well as of more complex dives (Optional) and the study of new technical elements.

Dry-land training has two main objectives: the first is to train the general and specific motor skills necessary for maintenance and improvement of performance standards (strength and flexibility); the second is to study new technical elements through the use of special equipment. For sports like diving that require perfect artistry, coordination or very specific skills, the periodization plan, like in the other sports, can be structured as monocycle, bicycle or tricycle depending on the number and distribution of competitions. Unlike the other sports, plans must take in to account the amount of time the divers will spend learning, repeating and perfecting dives and competition routines (ie, the sequence of dives performed in competition) and the ratio with the development of physical abilities such as strength and flexibility.

Usually, an elite training program is prescribed according to external training load parameters (ie, type and number of dives, and total duration of the training session). However, the same external load could elicit different responses in athletes, depending on their fitness and skill level. Furthermore, a diving training session might include several athletes performing a different number and type of dives. Because the optimization of training involves the precise quantification of a training stimulus, there is a need for a useful and practical method that can correctly monitor the internal training load to optimize the athlete’s performance.

To integrate the components of training into a single term that allows a systematic analysis approach to training, some authors have used athlete’s heart rate responses expressed as a percentage of individual maximal heart rate. However, the use of heart rate as a measure of exercise intensity has several limitations when evaluating short all-out bouts followed by long rest intervals and heart rate monitors often suffer technical failures when the athletes dive into the pool.

Based on the understanding that athletes can inherently monitor the physiological stress their body experiences during exercise, subjective ratings of perceived exertion (RPE) have been assessed using category-ratio or visual analog (VAS) scales. Furthermore, several authors have examined the quantification of training loads in different sports by multiplying the athlete’s RPE for the total duration (minutes) of the training session. Despite session-RPE and heart rate methods showing high correlation coefficients (range: 0.50–0.90), it might differ in relation to sport-specificity.

To our knowledge, no study has previously investigated the practical and inexpensive session-RPE method to quantify the internal training load in diving. Thus, the aim of the present study was to evaluate session-RPE, measured both with the modified CR-10 Borg scale and with the 100-mm VAS, as a useful method of monitoring training load during training sessions in elite divers.
Methods

Methodology

To assess the effectiveness of session-RPE in quantifying internal training load in diving, the Edwards heart rate method\textsuperscript{22} was used as a reference measure.\textsuperscript{6,7,11,13,19–21} This method was chosen because it has previously been established as an objective physiological measurement of calculating the internal training load.\textsuperscript{23} Specifically, the Edwards heart rate method determines individual internal training load by expressing the heart rate recordings as percentages of the athlete’s estimated maximal heart rate (HR$_{\text{max}}$) (ie, 220 – age), multiplying by a specific factor the accumulated time (ie, minutes) in five heart rate zones of individual HR$_{\text{max}}$ (ie, 50–60% = 1; 60–70% = 2; 70–80% = 3; 80–90% = 4; 90–100% = 5), and summing the scores (Figure 1).

To verify whether divers better evaluate their RPE when verbal anchors of a fixed scale are provided\textsuperscript{14,24} or when they are free to indicate their training intensity without being influenced by verbal links,\textsuperscript{14,15} both the Italian translation of the Borg CR-10 scale\textsuperscript{12} modified by Foster\textsuperscript{7} and a 100-mm visual analog scale (VAS) were used. The Borg CR-10 RPE scale is based on a category-ratio scale (ie, from “rest” to “maximal”), which translates the athlete’s perception of efforts into a numerical score between 0 and 10. Conversely, the visual analog scale (VAS) is a 100 mm plain line, with its left end representing a very low training intensity session and its right end an extremely intense training session. Consequently, athletes mark the amount of exertion they experienced with minimum constraints.

Because some authors\textsuperscript{14,15,25} hypothesized that VAS and CR-10 scales discriminate differently depending on the exercise intensity, their use during diving training sessions was tested. Furthermore, the total number of dives and their total and mean degree of difficulty were correlated to the internal training load methods (ie, session-RPE and Edwards heart rate). In fact, the degree of difficulty may be a useful tool to quantify the intensity of the external training load in diving.

Subjects

The local ethical committee approved this study and written information of the potential risks and benefits associated with participation and oral instruction were provided to three male (age, 25.7 ± 6.1 y; stature, 1.71 ± 0.06 m; body mass, 66.7 ± 1.2 kg) and three female (age, 25.3 ± 0.6 y; stature, 1.63 ± 0.05 m; body mass, 58.3 ± 4.0 kg) springboard divers who signed an informed consent. The athletes had to fulfill the following inclusion criteria: (1) compete at national and international (ie, Olympic Games and Diving World Championship) levels, (2) have at least 10 y of previous diving training (consisting at least of 20 h/wk) under the supervision of a coach, (3) be members of the National Team for at least 3 y.

Design

Each athlete was monitored during six training sessions within a week (ie, 1 and 3 m springboard performances) performed as a part of the preparatory phase of the yearly plan in the same swimming pool (Table 1). The coach designed and implemented a different number and typology of dives for each athlete and no attempt was made to manipulate the experimental condition.
Figure 1 — Schematic example of the Edwards summated HR zone method. The amount of time within five HR zones calculated on percentage of HR$_{\text{max}}$ (i.e., 50–60% = 1; 60–70% = 2; 70–80% = 3; 80–90% = 4; 90–100% = 5) is multiplied by the value of the zone and summated to derive a summated HR score.
Table 1  The weekly training schedule

<table>
<thead>
<tr>
<th>Day</th>
<th>Morning training</th>
<th>Afternoon training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>1 m—voluntary dives</td>
<td>dry-land training</td>
</tr>
<tr>
<td>Tuesday</td>
<td>1 m—optional dives</td>
<td>dry-land training</td>
</tr>
<tr>
<td>Wednesday</td>
<td>1 m—basic skills</td>
<td>1 m voluntary dives</td>
</tr>
<tr>
<td>Thursday</td>
<td>3 m—optional dives</td>
<td>dry-land training</td>
</tr>
<tr>
<td>Friday</td>
<td>3 m—basic skills</td>
<td></td>
</tr>
</tbody>
</table>

Note. Basic skills: take-off, line up, come-out, entries. Voluntary dives and Optional dives. Dry-Land training: strength and flexibility workouts.

Before the training session, a heart rate transmitter belt (Team System, Polar, Kempele, Finland) was placed on the athlete’s chest. The diver’s heart rate was recorded as mean values over 5 s periods. Data stored in the belt were subsequently downloaded onto a portable computer using the specific software (Polar Precision software version 4, Kempele, Finland). The beginning of warm-up and the end of the cool-down phase were registered to elapse extra recorded data.

One week before the experimental sessions, the athletes were familiarized with the CR-10 and VAS scales. During the familiarization session, each subject was given instructions on the use of the RPE and the VAS scales. For the CR-10, standard instructions and anchoring procedures were explained. For the VAS scale, athletes were instructed that the left end of the line represents a very low training intensity session and the right end of the line represents an extremely intense training session and that they are free to mark the location on the 100-mm line corresponding to the amount of exertion they experienced. To avoid the cases in which particularly difficult or easy elements practiced toward the end of the training session would dominate the subject’s overall rating, divers were asked to rate the intensity of their training 30 min after each experimental session using both the CR-10 and the VAS. The administration of the RPE scales was randomized and a 3 min delay between ratings was observed to avoid interferences in assessing scores. Finally, the individual CR-10 session-RPE and VAS session-RPE scores were computed by multiplying the duration of the training session by RPE values.

Statistical Analysis

All data are presented as mean values and standard deviations. Statistical analyses were performed using the SPSS statistical package (ver. 17 SPSS Inc., USA). The relationships between the assessment methods were estimated using Pearson product-moment correlation as well as the coefficient of determination ($r$ = correlation coefficient and $R^2$ = coefficient of determination). Furthermore the 95% confidence interval (95% C.I.) for the correlation coefficients were calculated. Edwards’s heart rate zone method was correlated with CR-10 session-RPE and VAS session-RPE. Correlation analyses were performed overall, for each training session and for each subject. Overall correlation analyses for external training load parameters (ie, number of dives, total and mean degree of difficulty) with respect to
Edwards’s heart rate method, CR-10 and VAS session-RPE were also performed. To minimize Type I error associated both with small sample and multiple correlation analysis involving the same subjects, the level of statistical probability for all correlation/regression coefficients was set at $P < .01$.

**Results**

During the six training sessions, mean heart rate was $112 \pm 16$ beats·min$^{-1}$. The corresponding intensity of effort was $57 \pm 8\%$ of individual HR$\text{max}$. Values for HR$\text{peak}$ were $152 \pm 17$ beats·min$^{-1}$. Peak intensity of effort was $76 \pm 8\%$ of individual HR$\text{max}$. Figure 2 shows the pattern of RPE based training load (CR-10 session-RPE and VAS session-RPE) and Edwards’s HR zone method during the six training sessions. The VAS session-RPE was standardized to CR-10 session-RPE to fit the graph.

Analyses showed overall significant ($P < 0.01$) correlations between Edwards’s heart rate, CR-10 ($r = .81; R^2 = .66$) and VAS session-RPE ($r = .74; R^2 = .55$).

Correlation coefficients between Edwards’s heart rate method, CR-10 and VAS session-RPE, for the six training sessions, are reported in Table 2 ($r$ range: 0.71–0.96; $R^2$ range: 0.50–0.92, $P < .01$); correlation coefficients between the same parameters for the individuals are showed in Table 3 ($r$ range: 0.67–0.96; $R^2$ range: 0.44–0.92, $P < .01$).

For external training load parameters, only the mean degree of difficulty of dives showed significant correlations ($r = .76; R^2 = .58, P < 0.01$) with respect to the internal training load parameters (Table 4).

**Discussion**

According to the literature$^{6,7,11,13,19-21}$, session-RPE seems to be a valuable tool for the evaluation of the internal training load in diving, showing a significant correlation ($r$ range 0.71–0.96) with respect to the Edwards’ heart rate method.

This statement seems to be incongruous if we take into account that diving is mainly dependent on skills rather than physiological fitness, and that the session-RPE is an indicator of the physiological loading as well. However, we must consider that the RPE represents the athlete’s own perception of training stress, which can include both physical and psychological stress$^{27}$ and that the session-RPE method can be considered a global indicator of exercise intensity, providing a measure of internal training load including physiological and psychological factors.$^{28}$

In a previous study,$^{29}$ in which we investigated the effectiveness of training diaries in diving, the athletes were asked to express (on a VAS scale) the rate of perceived exertion (RPE) and, on a separate VAS scale, the “mental” perception of fatigue as well. This scale was added because it was assumed that training complex skills requires a “mental effort” (as also reported by divers). Results showed that there were no differences between the perception of mental and physical fatigue even when the scales were reversed to avoid interferences in assessing scores.

These result seem to substantiate the idea that RPE represents the athlete’s own perception of both physical and psychological training stress, and allows us to speculate that session-RPE may be a useful tool in monitoring training load in diving.
Figure 2 — Pattern of RPE-based training load (CR-10 session-RPE and VAS session-RPE) and Edwards’s HR zone method during the six training sessions. (The VAS session-RPE was standardized to CR-10 session-RPE to fit the graph.)
Table 2  Training sessions correlation (r) between Edwards’s HR zone method and measures of session-RPE

<table>
<thead>
<tr>
<th>Training Session</th>
<th>CRPE</th>
<th>VRPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>C.I. (95%)</td>
</tr>
<tr>
<td>1 m—voluntary dives</td>
<td>0.88 (0.24 to 0.99)</td>
<td>0.77</td>
</tr>
<tr>
<td>1 m—optional dives</td>
<td>0.82 (0.03 to 0.98)</td>
<td>0.67</td>
</tr>
<tr>
<td>1 m—basic skills</td>
<td>0.72 (–0.22 to 0.97)</td>
<td>0.52</td>
</tr>
<tr>
<td>1 m—voluntary dives</td>
<td>0.78 (0.08 to 0.97)</td>
<td>0.61</td>
</tr>
<tr>
<td>3 m—optional dives</td>
<td>0.96 (0.68 to 0.99)</td>
<td>0.92</td>
</tr>
<tr>
<td>3 m—basic skills</td>
<td>0.74 (–0.18 to 0.98)</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Note. CRPE = CR-10 session-RPE, and VRPE = VAS session-RPE. Values for R² and the 95% confidence interval, C.I. (95%), are also reported.

Table 3  Individual divers’ correlation (r) between Edwards’s HR zone method and measures of session-RPE

<table>
<thead>
<tr>
<th>Diver</th>
<th>CRPE</th>
<th>VRPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>C.I. (95%)</td>
</tr>
<tr>
<td>D1</td>
<td>0.86 (0.16 to 0.98)</td>
<td>0.73</td>
</tr>
<tr>
<td>D2</td>
<td>0.91 (0.38 to 0.99)</td>
<td>0.82</td>
</tr>
<tr>
<td>D3</td>
<td>0.87 (0.19 to 0.98)</td>
<td>0.76</td>
</tr>
<tr>
<td>D4</td>
<td>0.72 (–0.22 to 0.97)</td>
<td>0.51</td>
</tr>
<tr>
<td>D5</td>
<td>0.87 (0.19 to 0.98)</td>
<td>0.76</td>
</tr>
<tr>
<td>D6</td>
<td>0.70 (–0.26 to 0.96)</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Note. CRPE = CR-10 session-RPE, and VRPE = VAS session-RPE. Values for R² and the 95% confidence interval, C.I. (95%), are also reported.

Table 4  Correlation coefficients between external training load parameters (ie, total number of dives, total degree of difficulty, average degree of difficulty), Edwards’s HR method and session-RPE

<table>
<thead>
<tr>
<th>External Training Load Parameters</th>
<th>Edwards’s HR</th>
<th>CRPE</th>
<th>VRPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>R²</td>
<td>r</td>
</tr>
<tr>
<td>Total number of dives</td>
<td>0.31</td>
<td>n.s.</td>
<td>0.18</td>
</tr>
<tr>
<td>Total degree of difficulty</td>
<td>0.34</td>
<td>n.s.</td>
<td>0.14</td>
</tr>
<tr>
<td>Average degree of difficulty</td>
<td>0.54*</td>
<td>0.29</td>
<td>0.75*</td>
</tr>
</tbody>
</table>

Note. CRPE = CR-10 session-RPE, and VRPE = VAS session-RPE. *Statistically significant (P < .01).
The percentage of variance not accounted for by the heart-rate-based method ($R^2$ range from 0.50 to 0.90) in the present study may be due to the numerous extraneous factors that contribute toward a diver’s personal perception of the difficulty of the training session. These considerations led us to take into account the parameters of the external load (the number of dives and their difficulties) with the aim to explain the variance not accounted.

We also have assumed that it could be more useful to calculate the session-RPE multiplying the RPE by the numbers of dives performed in the session more than for the training total duration. But the total number of dives (that expresses the training volume) does not represent the complexity of the dives (skills) performed. On the contrary, the coefficient of difficulty actually expresses the difficulty of the dive (which is a parameter of training intensity). Our results showed that number of dives and total degree of difficulty are not correlated with session-RPE (even if multiplied by RPE; results not reported). The correlation with session-RPE was found only with the mean degree of difficulty ($r = .75$) probably because the mean value takes into account that the training session total degree of difficulty could be due to a high number of dives with a low degree of difficulty.

Nevertheless, the correlation found between session-RPE and HR method—despite the lack of consistency of the correlation reported in some cases (Table 2 and 3), mainly due to the small sample size—corroborates the hypothesis that session-RPE method could be a useful tool to monitor internal training load in divers, in addition to being inexpensive, easy to interpret, and not presenting technical problems when the diver enters into the pool (eg, during a month of training, we were able to obtain reliable heart rate data only for six weekly training sessions).

Another result obtained in this study concerns the use of the VAS. Despite the claims of some authors that the CR-10 better discriminates all-out exercise bouts and the contentions of others that the VAS scale is better able to differentiate moderate levels of training intensities, in the present study CR-10 and the VAS scales proved to be interchangeable to quantify diving session-RPE. Considering that the quantification of the training load is crucial for monitoring the athlete’s adaptation to training, the coach could have immediate feedback using the CR-10 scale, whereas athletes could use the VAS scale when filling in on-line training diaries.

**Practical Applications and Conclusion**

To obtain optimal results from a successful periodized plan, monitoring exercise internal training load is fundamental. The daily and weekly training loads allow the coaches to verify the periodization plan and to avoid the maladaptive responses that may be objectively documented as distinct musculoskeletal injuries, such as alterations in muscle strength, flexibility or balance; changes in joint range of motion; or stress reactions in bone.

Once the training load is calculated, it is possible to calculate other training parameters (eg, monotony and strain) that can give important feedback on the adaptation to training. The present results provide support for the use of the session-RPE method as an estimate of training load of diving. These findings could be also useful for coaches of other closed-skill sports (eg, artistic gymnastics,
rhythmic gymnastics, figure skating) where athletes practice sequences of different levels of difficulty.

Moreover, data showed (Table 4) that mean degree of difficulty could be considered a useful parameter for describing the external load of training more than the number of dives and the total degree of difficulty, especially when taking into account that the total degree of difficulty of the training session could be due to a high number of dives with a low degree of difficulty.

Considering that the present study included only training sessions of the preparatory phase, further research is needed to assess whether the validity, reliability, and sensitivity of the session-RPE method varies in relation to different phases (ie, precompetitive and competitive) of the yearly plan.

References