The relationships between subjective and objective indicators of training load in female handball players

Running Title: Relationships between load indicators in handball

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Abstract

This study investigated the relationships between subjective and objective indicators of training load in female handball players. Twelve female handball players (age: 20.1±1.2 years, height: 164.3±4.2 cm, and weight: 61.8±4.1 kg) belonging to the first division of a university league were included in the study. The training load was investigated over a nine-week period of the competition phase. The subjective load indicator was the session rating of perceived exertion (sRPE), and the objective load indicators were total distance, Player Load™, and heart rate-based training load (HRTL). We observed 20.5±2.3 sessions for each player. The sRPE demonstrated significant relationships (p<0.05) with all objective load indicators, with correlation coefficients r=0.73±0.09, 0.73±0.08, and 0.75±0.10 for total distance, Player Load™, and HRTL, respectively. All the relationships were very strong (0.7<r<0.9). These results reveal the potential validity of sRPE use in handball and suggest that the sRPE is an indicator that reflects the characteristics of both biomechanical and physiological load indicators.

Key Words: Handball; Team sports; Training load; session-RPE; GPS technology; Heart rate
女子ハンドボール選手におけるトレーニング負荷の主観的指標と客観的指標の関係について

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抄録

本研究は、ハンドボールにおけるトレーニング負荷の主観的指標と客観的指標との関係について調査を行った。12名の大学リーグに所属する女子ハンドボール部選手（年齢20.1±1.2歳、身長164.3±4.2cm、体重61.8±4.1kg）を対象とし、9週間のトレーニング負荷を調査した。主観的負荷指標にはsession-RPE（sRPE）を用いて、客観的負荷指標には総移動距離（Player Load™、心拍負荷（HRTL））を用いた。各プレーヤー平均20.5±2.3セッションのデータが観察された。sRPEは全ての客観的指標間で有意な関係が認められ（p<0.05）、相関係数は総移動距離r=0.73±0.09、Player Load™r=0.73±0.08、HRTLr=0.75±0.10であり、いずれもとても強い関係（0.7<r<0.9）であった。これらの結果は、ハンドボールにおけるsRPEの利用の妥当性を明らかにし、sRPEが生体力学的負荷指標と生理学的負荷指標の両方の特性を反映した指標であることを示唆している。
Introduction

Training in team sports is conducted with the aim of maximizing athletic performance in target competitions while reducing the risk of sports injuries and illnesses. For this purpose, training should be conducted according to an annual plan based on the competition schedule and adjusted so that peak performance is achieved at an appropriate time. To ensure effective training, it is important to prescribe appropriate training loads and monitor them.

According to the Olympic Consensus Statement on Training Load published in 2016, a load is defined as “the sport and non-sport burden (single or multiple physiological, psychological, or mechanical stressors) as a stimulus that is applied to a human biological system (including subcellular elements, a single cell, tissues, one or multiple organ systems, or the individual).” In recent years, the use of global positioning systems (GPS), inertial measurement units, accelerometers, and heart rate monitors to measure training load has enabled objective load measurement using biomechanical data, such as individual running distance, acceleration load, number of accelerations/decelerations, and number of collisions, as well as physiological data, such as heart rate. In addition, these objective load indicators have been used to monitor daily training and applied for various purposes, such as performance indicators and prevention of sports injuries, illnesses, and overtraining. Thus, whereas the effectiveness of evaluation using objective load indicators has been described, these methods have been found to be considerably expensive, relatively complicated, and difficult to use in some sports.

In order to solve these problems, subjective load indicators have been used to monitor load in various team sports as alternatives to objective measurement. Among them, the session rating of perceived exertion (sRPE), developed by Foster et al., is a subjective load indicator that can be calculated by multiplying the subjective training
intensity by the training duration, can be measured at low cost, and is simple to use.

After the development of the sRPE, relationships between the sRPE and objective load indicators have been observed in various team sports, such as soccer, rugby, Australian football, and basketball. In sports where the validity of the sRPE has been verified, further research is being conducted to prevent injury and improve performance.

The use of the sRPE allows for a more cost-effective and easily accessible method of monitoring an individual athlete’s load.

However, in sports where the relationships between the sRPE and objective load indicators remain unclear, the use of the sRPE as a load indicator may not be appropriate because physical demands vary according to the athletic characteristics of different disciplines. Handball, like soccer, rugby, Australian football, and basketball, is a sport in which attack and defense are frequently switched, the running distance is relatively long, and the frequency of lateral movements and changes of direction is high. Accordingly, handball has similar elements to other sports; nevertheless, it also has physical demands unique to its nature, such as intense physical contact, which is not permissible in soccer or basketball. Therefore, the sRPE is considered to be related to both biomechanical and physiological aspects of objective load indicators in handball.

There have been studies that have adapted the sRPE to handball players with the aim of identifying physical demands in matches and small-sided games. However, the validity of using the sRPE to continuously measure daily training load has not been demonstrated. It is important to clarify the relationship between the sRPE and objective load indicators in handball training in order to implement simpler and more effective training monitoring. Therefore, this study aimed to examine the relationships between subjective and objective indicators of training load in handball.
**Materials and Methods**

1. **Subjects**

   Twelve female handball court players (age: 20.1±1.2 years, height: 164.3±4.2 cm, and weight: 61.8±4.1 kg) belonging to the Kanto University Women’s Handball League First Division were selected as subjects.

   The purpose and content of this study were fully explained to the subjects verbally or in writing, and their written consent was obtained. This study was approved by the Ethics Committee of the Graduate School of Comprehensive Human Sciences, University of Tsukuba (approval number: 020-6).

2. **Procedures**

   During the study period from October 26 to December 25, 2020, subjective and objective load indicators were measured daily from the beginning to the end of each training session (herein referred to as training session) of the target team. The study period was the competition phase of the 72nd Japan National Championships held from December 24 to 28, 2020. The measurements were performed on the outdoor handball court where the target team was training daily. Among the training sessions, those conducted on the handball court (including warm-up, technical training, tactical training, and match training) were included in the analysis, except for strength training.

3. **Subjective indicator of training load**

   The sRPE was used as the subjective load indicator. To calculate the sRPE, each subject entered their subjective training intensity (RPE) using a web questionnaire after each daily training, and Borg’s 10-point subjective training intensity scale (Category Ratio-10, CR-10) was used to measure the RPE (Table 1). After data collection, the sRPE was calculated by multiplying the training duration (min) by the
RPE value obtained (Equation 1).

(Equation 1)  \( s\text{RPE} \text{ (AU)} = \text{training duration (min)} \times \text{RPE (CR-10)} \)

4. Objective indicators of training load

Objective load indicators were measured using a GPS device/accelerometer and heart rate monitor.

The GPS device was a Catapult Vector S7 (Catapult, Melbourne, Australia), which was mounted in a pocket on the back of a special vest for measurement. The sampling frequency was set to 10 Hz, and that of the device’s in-built three-axis accelerometer was set to 100 Hz. After the measurement was completed, the data were synchronized to a personal computer, and the total distance and Player Load™ data were acquired as objective load indicators using dedicated software (Openfield™, Catapult, Melbourne, Australia). Player Load™ is calculated using a three-axis accelerometer, which can capture the player’s movement in three planes. It can be measured even in environments where GPS data cannot be obtained and is widely used as an objective load indicator in various team sports\(^{11,17,18,28}\). Player Load™ (arbitrary unit, AU) was calculated as follows:

(Equation 2)  \[
\text{Player Load (AU)} = \sum_{t=0}^{t=n} \sqrt{((\text{fwd}_{t+1} - \text{fwd}_t)^2 + (\text{side}_{t+1} - \text{side}_t)^2 + (\text{up}_{t+1} - \text{up}_t)^2)}
\]

where fwd=forward acceleration, side=sideways acceleration, up=upwards acceleration, and t=time

Heart rate (HR) was measured using the Polar H10 heart rate monitor (Polar Electro Co., Ltd., Kempele, Finland), which was attached to the chest of each subject. In order
to measure the maximum HR (HRmax), a 20-m shuttle run test was conducted before the study period (October 2020). From the obtained HR data, the heart rate-based training load (HRTL) was calculated using the method employed by Edwards et al.29 First, the HRTL was classified into five intensity zones based on the HRmax and assigned an index. Thereafter, each index was multiplied by the duration (min) in each zone and summed to calculate the HRTL (Equation 3).

\[
\text{HRTL (AU)} = (\text{duration in zone 1} \times 1) + (\text{duration in zone 2} \times 2) + (\text{duration in zone 3} \times 3) + (\text{duration in zone 4} \times 4) + (\text{duration in zone 5} \times 5)
\]

where zone 1=50–59.9% HRmax, zone 2=60–69.9% HRmax, zone 3=70–79.9% HRmax, zone 4=80–89.9% HRmax, and zone 5=90–100% HRmax

5. Statistical analysis
For each load indicator, the mean ± standard deviation (SD) of the training sessions for all subjects was calculated. Subsequently, Pearson’s product-rate correlation coefficient was used in the analysis to examine the relationship between the subjective and each of the objective load indicators. RPE has been shown to be influenced by various internal factors, such as years of competition, performance level, and fatigue state.14,30 Therefore, in this study, as in other studies13,15,31 that investigated the relationship between subjective and objective load indicators, the correlation coefficient was calculated for each subject and subsequently presented as the mean ± SD of all subjects and each playing position. Correlation strength was classified as follows: trivial (r<0.1), weak (0.1<r<0.3), moderate (0.3<r<0.5), strong (0.5<r<0.7), very strong (0.7<r<0.9), almost perfect (>0.9), and perfect (r=1). Since there were some missing values of HRTL during the measurement, the sRPE data corresponding
to the missing values of HRTL were excluded from the analysis. All statistical analyses were performed using IBM SPSS Statistics (version 27.0; IBM, Chicago, IL, USA), and statistical significance was set at p<0.05.

**Results**

Training load data had the following frequencies: sRPE, 246; total distance, 246; Player Load™, 246; and HRTL, 241, excluding missing data. Each player averaged 20.5 ± 2.3 sessions, and the mean training activity time per session was 1:39:30 ± 0:16:55. The activity time for each training session by training mode is shown in Fig. 1.

The means ± SDs of the subjective and objective load indicators for all training sessions are shown in Table 2. The sRPE was 409.8±151.7 AU, total distance 5480.8±1178.1 m, Player Load™ 701.9±158.9 AU, and HRTL 256.1±73.3 AU (Table 2). The pattern of each training load indicator is shown in Fig. 2.

There were significant relationships between the sRPE and all objective load indicators (p<0.05), and the mean correlation coefficients in all subjects were r=0.73±0.09, r=0.73±0.08, and r=0.75±0.10 for total distance, Player Load™, and HRTL, respectively, all of which reflected very strong correlations (Table 3). Regarding playing position, there was a significant relationship between sRPE and objective load indicators for all positions, with back and pivot being very strong and wing being strong.

The relationships between the objective load indicators were almost perfect, with r=0.98±0.02 for total distance and Player Load™, r=0.90±0.06 for total distance and HRTL, and r=0.91±0.04 for Player Load™ and HRTL.
Discussion

This study aimed to clarify the relationships between subjective and objective indicators of training load in handball. The sRPE, total distance, Player Load™, and HRTL were measured in training sessions conducted on a handball court, and the relationship between each variable was examined. The results revealed significant correlations (p<0.05) between the subjective (sRPE) and objective (total distance, Player Load™, and HRTL) load indicators, and the correlations were very strong for all variables. These results suggest the potential validity of sRPE use in handball and that sRPE is an indicator that reflects the characteristics of both biomechanical (total distance, Player Load™) and physiological (HRTL) load indicators. In addition, the relationship between sRPE and total distance has not been investigated in previous studies because it is generally impossible to measure the total distance using GPS in indoor sports. Notwithstanding, the relationship between the two indicators could be examined in this study because the daily training location of the target team was an outdoor court; thus, the validity of the study was confirmed.

In order to use the sRPE as an alternative method in environments where it is difficult to measure objective load indicators, its relationships with objective load indicators have been investigated in various team sports as in this study. In soccer, strong to very strong relationships of sRPE with total distance (r=0.61–0.85), Player Load™ (r=0.62–0.83), and HRTL (r=0.57–0.85) have been reported. In Australian football, the relationships of sRPE with total distance (r=0.81), Player Load™ (r=0.83), and HRTL (r=0.83) were reportedly very strong. Svilar et al. and Manzi et al. conducted a study on professional basketball players and reported that the relationships of sRPE with Player Load™ (r>0.80) and HRTL
(r=0.85) were very strong. In addition, handball, from which this study’s sample was taken, is a sport characterized by high-intensity movements, such as sprinting, change of direction, and physical contact, which are repeatedly performed while the body moves during frequent changes from attack to defense. It has characteristics similar to those of soccer, Australian football, and basketball\textsuperscript{22-24}. In order to measure the training load based on these characteristics of handball, we used the total distance, Player Load\textsuperscript{TM}, and HRTL as objective indicators. In particular, Player Load\textsuperscript{TM} is a load calculated from a three-axis accelerometer and is considered to be more suitable for measuring high-intensity movements because it can capture the player’s movement in three planes and has a high sampling frequency\textsuperscript{11,17,18,28}. Thus, the very strong correlation coefficients between the sRPE and the objective load indicators were found as in previous studies in other team sports. These results reveal the potential validity of sRPE use in handball.

In addition, the period during which this study was conducted was the competition phase. Many previous studies have investigated the training load over a period that included the competition phase\textsuperscript{8,11,12,16,18,19}. In general, the training involved in these team sports incorporates practices that simulate the physical demands of real matches, such as match training and tactical training, and the frequency of such practices increases significantly during the competition phase\textsuperscript{33}. Therefore, it is conceivable that the sRPE exhibited very strong correlations with the objective load indicators in this study due to training-period classifications similar to those of other previous studies. Nonetheless, according to a study by Scanlan et al.\textsuperscript{17} of semiprofessional basketball players from the general to specific preparation phase, excluding the competition phase, only a moderate correlation coefficient (r=0.49) was obtained, and the relationships between the sRPE and objective load indicators tended to be weaker than in other previous studies. This suggests that the relationships between the sRPE and
objective load indicators may differ according to the type of training period, and further investigation specific to each training period is necessary. Regarding playing position, there was a significant relationship between sRPE and the objective load indicators for all positions, with back and pivot being very strong and wing being strong. In the present study, handball training was the subject of analysis, and many of the training were common to all positions. Therefore, the relationship between sRPE and objective load indicators did not differ significantly by position.

**Study limitations**

Although this study provides new insights for coaches and sports scientists regarding the monitoring of training loads in handball, certain limitations need to be acknowledged. First, the results of this study only included players of one female handball team belonging to the first division of the university league; therefore, the findings are difficult to generalize. In the future, it may be prudent to measure the effects of age and sex in various teams. Second, the present study investigated the overall training load (including warm-up, technical training, tactical training, and match training) in order to reduce the burden on the subject and to obtain reliable data, but did not measure individual training loads for each training period or training mode. These factors might have influenced training load and altered the relationships between the indicators. Therefore, the loads of each training period and training mode should be investigated separately, and further studies on the characteristics of training loads are warranted under a measurement system that considers the burden on the subject.

**Conclusion**
Very strong relationships were observed between the subjective (sRPE) and objective (total distance, Player Load™, HRTL) load indicators, thus suggesting that the sRPE is valid in monitoring training load during handball activities.

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We express our great appreciation to the study participants.

Conflict of Interests

The authors declare no conflict of interest associated with this study.

Author Contributions

Conceived and designed the study: AT and HS. Performed the study: AT. Analyzed the data: AT. Interpreted the data: AT, TK, SM, NY, and HS. Wrote the manuscript: AT. All authors approved the final version of the manuscript.

References


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Table 1 Borg’s CR10-scale modified by Foster et al.1

<table>
<thead>
<tr>
<th>Rating</th>
<th>Descriptor</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>Rest</td>
</tr>
<tr>
<td>1</td>
<td>Very, Very Easy</td>
</tr>
<tr>
<td>2</td>
<td>Easy</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat Hard</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very Hard</td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Maximal</td>
</tr>
</tbody>
</table>
Table 2: Training load indicators for all sessions [Mean±SD]

<table>
<thead>
<tr>
<th>Variables</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>sRPE (AU)</td>
<td>246</td>
<td>409.8</td>
<td>151.7</td>
</tr>
<tr>
<td>Total distance (m)</td>
<td>246</td>
<td>5480.8</td>
<td>1178.1</td>
</tr>
<tr>
<td>Player Load (AU)</td>
<td>246</td>
<td>701.9</td>
<td>158.9</td>
</tr>
<tr>
<td>HRTL (AU)</td>
<td>241</td>
<td>256.1</td>
<td>73.3</td>
</tr>
</tbody>
</table>

Abbreviations: sRPE, session rating of perceived exertion; HRTL, heart rate-based training load; AU, arbitrary units
Table 3. Correlation coefficients between measures of objective and subjective training load indicators

<table>
<thead>
<tr>
<th>Subject</th>
<th>Position</th>
<th>Total distance × sRPE</th>
<th>Player Load × sRPE</th>
<th>HRTL × sRPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CB</td>
<td>0.85</td>
<td>0.83</td>
<td>0.83</td>
</tr>
<tr>
<td>2</td>
<td>CB</td>
<td>0.75</td>
<td>0.76</td>
<td>0.87</td>
</tr>
<tr>
<td>3</td>
<td>CB</td>
<td>0.79</td>
<td>0.80</td>
<td>0.74</td>
</tr>
<tr>
<td>4</td>
<td>LB</td>
<td>0.74</td>
<td>0.73</td>
<td>0.75</td>
</tr>
<tr>
<td>5</td>
<td>LB</td>
<td>0.59</td>
<td>0.62</td>
<td>0.74</td>
</tr>
<tr>
<td>6</td>
<td>RB</td>
<td>0.84</td>
<td>0.81</td>
<td>0.85</td>
</tr>
<tr>
<td>7</td>
<td>RB</td>
<td>0.76</td>
<td>0.77</td>
<td>0.79</td>
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<tr>
<td>8</td>
<td>PV</td>
<td>0.61</td>
<td>0.66</td>
<td>0.62</td>
</tr>
<tr>
<td>9</td>
<td>PV</td>
<td>0.81</td>
<td>0.83</td>
<td>0.78</td>
</tr>
<tr>
<td>10</td>
<td>LW</td>
<td>0.63</td>
<td>0.60</td>
<td>0.49</td>
</tr>
<tr>
<td>11</td>
<td>LW</td>
<td>0.80</td>
<td>0.74</td>
<td>0.72</td>
</tr>
<tr>
<td>12</td>
<td>RW</td>
<td>0.65</td>
<td>0.67</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Position (mean±SD)

| Back    | 0.76±0.08 | 0.76±0.07 | 0.79±0.05 |
| Pivot   | 0.71±0.10 | 0.74±0.09 | 0.70±0.08 |
| Wing    | 0.69±0.08 | 0.67±0.06 | 0.68±0.15 |

All subjects (mean±SD) very strong very strong very strong

Abbreviations: sRPE, session rating of perceived exertion; HRTL, heart rate-based training load; AU, arbitrary units; CB, center back; LB, left back; RB, right back; PV, pivot; LW, left wing; RW, right wing; Back, CB+LB+RB; Wing, LW+RW. All correlations were significant (p<0.05)
Fig. 1 Activity time for each training session and each training mode (warm-up, technical training, tactical training and match training).
Fig. 2 Pattern of (A) sRPE, (B) total distance, (C) Player Load™, and (D) HRTL of the whole team ($N=12$) over a nine-week period (22 training sessions). Abbreviations: sRPE, session rating of perceived exertion; HRTL, heart rate-based training load; AU, arbitrary units.