

# Quantification of external and internal match loads in elite female team handball

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**ABSTRACT:** To assess concurrently the external and internal match loads in elite female team handball players and to verify the differences in match loads between matches characterized by different durations. Eight elite female court handball players (mean  $\pm$  SD; age  $23.0 \pm 2.1$  years; stature  $173.5 \pm 4.9$  cm; body mass  $67.8 \pm 6.8$  kg) belonging to the same elite female handball team were investigated. Individualized internal and external match loads were monitored during seven 1st Division Lithuanian Women's Handball League [Lietuvos Moteru Rankinio Lyga (LMRL)] matches and seven Women's Baltic Handball League (WBHL) matches during the 2017/18 season. The LMRL and WBHL matches were characterized by different durations (two 30-min halves and two 20-min halves for LMRL and WBHL, respectively). The investigated external load measures were total player load (PL) and PL per minute (PL.min<sup>-1</sup>), while internal load measures were match load calculated from session rating of perceived exertion (S-RPE) and percentage of maximum heart rate (%HR<sub>max</sub>). The main outcomes revealed a PL.min<sup>-1</sup> of  $\sim 9$  AU and  $\sim 84\%$  of HR<sub>max</sub> per match. Moreover, significantly higher total PL ( $p < 0.001$ ; ES (effect size) = Moderate) and match load calculated from S-RPE ( $p < 0.05$ ; ES = small to moderate) were found in LMRL compared to WBHL. Conversely, no statistically significant differences were found for PL.min<sup>-1</sup> and %HR<sub>max</sub> between the two leagues. The main results indicate that elite female handball matches require high physical and physiological demands. Additionally, a longer match time corresponded to dissimilar responses in external and internal match loads, suggesting that coaches should monitor match loads with different strategies.

**CITATION:** Kniubaite A, Skarbalius A, Clemente FM, Conte D. Quantification of external and internal match loads in elite female team handball. *Biol Sport*. 2019;36(4):311–316.

Received: 2019-05-17; Reviewed: 2019-07-05; Re-submitted: 2019-07-11; Accepted: 2019-07-11; Published: 2019-10-10.

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**Key words:**

Training load  
Accelerometer  
Workload  
Match analysis  
IMU  
Physiological response

## INTRODUCTION

Team handball is a complex sport and the quantification of the match-play performance seems fundamental to provide coaches with useful information to design sound training sessions [1, 2, 3]. In this regard, previous investigations showed that team handball match-play imposes high physical and physiological demands on both male and female players [3, 4, 5, 6]. In the last few years, microtechnology has been adopted to determine elite female handball players' physical performance during official matches [6, 7, 8]. A previous study investigating the physical demand of a Norwegian elite female handball team documented an external load quantified as player load (PL) per min of  $8.82 \pm 2.06$  arbitrary units (AU), with  $3.90 \pm 1.58$  high intensity events (i.e. the sum of accelerations, decelerations, and change of directions) per minute [7]. These results demonstrated that elite female team handball players spend a considerable amount of energy performing high-intensity events, underlining the high demand of the matches.

While microtechnology provides indications about the external match load profile, it seems fundamental to concurrently assess the internal match load, which represents the players' psychophysiological responses elicited during matches [9]. Recently, Impellizzeri et al. [9] suggested the use of internal load as a primary measure when assessing athletes since players can experience different internal loads in response to similar external loads. A previous study investigating the internal match load in elite female team handball documented a quite high internal match load, showing that players reached  $>85\%$  of their maximal heart rate [10]. Additionally, it has been strongly suggested to concurrently monitor both internal and external load in court-based team sports due to the low commonality reported between them [11, 12]. In this regard, a previous study assessing the relationship between internal and external load measures documented moderate to large relationships with a  $R^2 < 38\%$ , suggesting that one should not assume a linear dose-response relationship between

internal and external training load measures [11]. Therefore, the assessment of both external and internal match loads in court-based sports such as team handball is warranted. To the best of our knowledge, only a few studies have concurrently monitored external and internal match loads in team handball [5, 10]. However, all these studies quantified the external load using video-based time-motion analysis techniques, while more recent technologies (i.e. micro-sensors) can provide more detailed movement analysis information [7]. In fact, the events derived from inertial sensors/accelerometers can be collected regardless of players' activity on the court, thus providing a greater potential to better understand the mechanisms of fitness and fatigue and reduce the dependency of tactical issues that occurs with typical analysis of distances or related changes of direction or velocity [13]. Therefore, it would be fundamental to assess concomitantly internal and external match loads via microtechnology.

Handball teams are also usually involved in different leagues during the in-season period. International matches have 60-min length (i.e. two 30-min halves separated by a 15-min break). However, in some countries, national and regional championships are characterized by different match lengths and break time, which might elicit different external and internal match load responses. The assessment of these differences might represent crucial information for team handball coaches and practitioners in order to optimize the training load prescription according to each league match demand. To the best of our knowledge, no previous investigation has focused on the comparisons in match workload between matches structured with different durations, thus calling for further investigations. Therefore, the aims of this study were: a) to assess concurrently the external and internal match loads in elite female team handball players;

b) to assess the differences in match load between leagues characterized by matches with different durations.

## MATERIALS AND METHODS

### Participants

Eight elite female court handball players [mean  $\pm$  SD; age 23.0  $\pm$  2.1 years; stature 173.5  $\pm$  4.9 cm; body mass 67.8  $\pm$  6.8 kg; percentage of fat mass 20.4  $\pm$  3.9 %, maximal heart rate ( $HR_{max}$ ) 186.6  $\pm$  12.3, maximum oxygen consumption ( $VO_{2max}$ ) 48.0  $\pm$  5.8 ml.kg<sup>-1</sup>.min<sup>-1</sup>, countermovement jump (CMJ) 41.5  $\pm$  0.92, Yo-Yo intermittent recovery test level 1 (YYIR1) 1033  $\pm$  450 m] belonging to the same female 1st Division Handball team were investigated. Seven players were members of the Lithuanian female national handball team. During this period, players typically completed 5 training sessions (including strength and conditioning sessions) lasting approximately 120 min and 1–2 games per week. Before commencement of the study all players were informed about the rationale of the study and provided informed consent. Ethical approval was obtained from the Local Institutional Research Committee of the Lithuanian Sports University.

### Design

Before the commencement of the study (i.e. pre-season period), players' anthropometric characteristics were assessed. Body mass parameters were calculated using a body composition analyzer (Tanita BC-418, Japan). Moreover, functional capacities (i.e.  $HR_{max}$  and  $VO_{2max}$ ) were assessed in the laboratory using an incremental treadmill test until exhaustion wearing a gas analyzer (Jaeger Oxycon Mobile, Germany). Moreover, players' power and fitness were assessed

**TABLE 1.** Information about the selected seven 1st Division Lithuanian Women's Handball League [Lietuvos moteru rankinio lyga (LMRL)] matches and seven Women's Baltic Handball League (WBHL) matches.

	Tournament period	T1 (Oct 27–29)	T1 (Oct 27–29)	T2 (Jan 12–14)	T2 (Jan 12–14)	T2 (Jan 12–14)	Singular game (Apr 11)	T3 (Apr 20–22)
WBHL	Game number	Match 1	Match 2	Match 3	Match 4	Match 5	Match 6	Match 7
	Opponent team	Galychanka	Garliava	Galychanka	Gardinas	Gomel	Garliava	Gomelis
	Game location	Home	Home	Away	Away	Away	Home	Away
	Final score	21–29 (lost)	35–29 (won)	20–14 (lost)	13–23 (won)	19–22 (won)	30–25 (won)	30–18 (lost)
	Season period	In-season	In-season	In-season	In-season	LMRL Final	LMRL Final	LMRL Final
LMRL	Game number	Match 1	Match 2	Match 3	Match 4	Match 5	Match 6	Match 7
	Opponent team	Garliava	Garliava	Garliava	Garliava	Garliava	Garliava	Garliava
	Game location	Away	Home	Away	Home	Home	Away	Home
	Final score	38–30 (lost)	32–33 (lost)	24–27 (won)	41–36 (won)	37–28 (won)	25–29 (won)	38–32 (won)

using a free-arms CMJ [14, 15] using Optojump (Microgate, Bolzano, Italy) and using the YYIR1 test applied on a regular-sized handball court [1].

Internal and external match loads were monitored for each investigated player during seven 1st Division Lithuanian Women's Handball League [Lietuvos Moteru Rankinio Lyga (LMRL)] matches and seven Women's Baltic Handball League (WBHL) matches during the 2017/18 season (from October 2017 to May 2018). The LMRL is the premier women's handball national competition in Lithuania, while the WBHL is played by two Lithuanian, two Belarusian and one Ukrainian team. Only teams classifying in the 1st and 2nd positions of their national leagues can qualify for the WBHL. Moreover, the investigated team was the only Lithuanian team participating in the Women's European Handball Federation Challenge Cup, which is considered the third-tier competition of European club handball (data from this cup were not collected). The LMRL and WBHL matches were characterized by different durations [LMRL matches = two 30-min halves separated by a 10-min break (similar to international women's handball matches); WBHL matches = two 20-min halves separated by a 10-min break]. This difference is due to the fact that WBHL is usually organized in 2–3-day tournaments during the in-season period with teams playing multiple matches in a short time (usually 3–4 matches in 3 days). The selected matches from WBHL and LMRL are shown in Table 1. The 6 WBHL matches were selected from three 3-day tournaments and one match was played against the other Lithuanian team one week before the third tournament (Table 1). Considering LMRL, four matches were played during the in-season period (October 2017 to February 2018) and three during the play-off period all against the same opponent, which is the other Lithuanian team participating in the WBHL.

All the investigated matches were preceded by a 30-min standardized warm-up, which was excluded from the analysis. For each investigated match we calculated match time, calculated as the time from the beginning to the end of the match including all stoppages (i.e. time-outs and half time break and in-match stoppages) and actual match time, identified as the time each player spent on court excluding all stoppage time. For both match time and actual match time, the following dependent variables were assessed: a) total PL; b) PL. min<sup>-1</sup>; c) match load calculated from session rating of perceived exertion (S-RPE). Additionally, percentage of maximal heart rate (%HR<sub>max</sub>) was calculated for actual match time only.

### Procedure

The external load (i.e. PL and PL. min<sup>-1</sup>) during each match was calculated using microsenors (Optimeye S5, Catapult Innovations, Melbourne, Australia). Each player was equipped with inertial measurement units placed in manufacturer-supplied neoprene vests for secure attachment between the scapulae and worn under their match jersey. Microsenors recorded triaxial accelerometer data at 100 Hz to calculate PL, which is defined as the instantaneous rate of change of acceleration divided by a scaling factor and is expressed as the

square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (X, Y and Z axis) and divided by 100 [16]. This external load measure has been previously used in team handball [6–8]. Microsensor data were downloaded with proprietary software (Catapult Openfield, v1.17; Catapult Innovations) to calculate PL and PL. min<sup>-1</sup>.

The internal match load was objectively monitored using HR chest belts (Polar Team System, Finland) and recorded data were matched with microsensor data and subsequently downloaded using the mentioned-above proprietary software. Data were then expressed as percentage of the HR<sub>max</sub> recorded during the YYIR1 or the highest value registered during the investigated matches. Additionally, internal match loads were subjectively assessed using the session-RPE method, which has been previously used to assess internal training load in team handball players [17]. Players were required to rate the intensity of each match ~30 min after their completion using the category ratio scale (CR-10) by answering the question: "How intense was your match?" [18]. Then match loads were calculated multiplying the session-RPE value by the match time or the actual match time in minutes [18].

### Statistical Analysis

Data are presented as mean ± SD for each dependent variable and were analyzed using a linear mixed model. One model for each dependent variable was constructed with league (LMRL vs. WBHL) as a fixed effect and player and match as a random effect. The influence of the fixed effect was assessed using the likelihood ratio test and creating full models (including the fixed effect) and comparing them with null models (excluding the fixed effect). Significance was set at  $p < 0.05$ . The magnitude of differences in all dependent variables between players competing in LMRL and WBHL was assessed using effect size (ES) statistics with 90% confidence intervals. Effect sizes were interpreted as  $< 0.2$  = trivial,  $0.2–0.6$  = small,  $0.6–1.2$  = moderate,  $1.2–2.0$  = large, and  $> 2.0$  = very large [19]. All statistical analyses were conducted using the lme4 package in R (R.3.0.2, R Foundation for Statistical Computing).

## RESULTS

The main results indicated a physical load of ~9 AU of PL. min<sup>-1</sup> and ~84% of HR<sub>max</sub> considering the actual match time in all the investigated matches. The differences between LMRL and WBHL are displayed in Table 2. The results showed that participants had a significantly longer match time ( $p < 0.001$ ; ES = very large) and actual match time ( $p = 0.001$ ; ES = small) in LMRL compared to WBHL. This difference corresponded to significantly higher total PL ( $p < 0.001$ ; ES = moderate) and a significantly higher match load calculated from S-RPE ( $p < 0.05$ ; ES = small to moderate) considering both match time and actual match time. Conversely, when considering PL. min<sup>-1</sup> and %HR<sub>max</sub>, no statistically significant differences were found between the two leagues.

## DISCUSSION

**TABLE 2.** Mean  $\pm$  standard deviation and statistical comparison for each dependent variable between matches characterized by different durations.

Dependent Variable	League		LMM	LMRL vs. WBHL		
	WBHL (20-min half)	LMRL (30-min half)		Mean difference (90%CI)	ES (90%CI)	ES Interpretation
Match time	64.1 $\pm$ 12.0	85.6 $\pm$ 4.0	<b>p&lt;0.001</b>	21.4 (18.6; 24.2)	3.51 (3.05; 3.97)	Very Large
Actual match time	31.0 $\pm$ 13.0	37.3 $\pm$ 13.3	<b>p=0.001</b>	6.3 (2.2; 10.4)	0.47 (0.17; 0.78)	Small
Total PL – Match time	313.8 $\pm$ 110.3	418.3 $\pm$ 141.2	<b>p&lt;0.001</b>	104.5 (64.8; 144.3)	0.83 (0.52; 1.15)	Moderate
Total PL – Actual match time	258.9 $\pm$ 109.1	335.0 $\pm$ 142.3	<b>p&lt;0.001</b>	76.1 (36.3; 115.8)	0.61 (0.29; 0.930)	Moderate
PL. min-1 – Match time	5.0 $\pm$ 1.4	5.0 $\pm$ 1.6	p=0.874	0.0 (-0.4; 0.5)	0.02 (-0.29; 0.33)	Trivial
PL. min-1 – Actual match time	9.2 $\pm$ 2.1	9.3 $\pm$ 2.1	p=0.532	0.1 (-0.5; 0.8)	0.06 (-0.25; 0.37)	Trivial
Match load – S-RPE * Match time	443.3 $\pm$ 176.0	630.1 $\pm$ 162.4	<b>p&lt;0.001</b>	185.8 (132.8; 238.9)	1.09 (0.78; 1.40)	Moderate
Match load – S-RPE * Actual match time	414.4 $\pm$ 191.0	490.3 $\pm$ 175.9	<b>p=0.003</b>	75.9 (18.3; 133.5)	0.41 (0.10; 0.72)	Small
%HR <sub>max</sub> – Actual match time	84.2 $\pm$ 6.7	84.8 $\pm$ 5.1	p=0.535	0.5 (-1.3; 2.4)	0.09 (-0.23; 0.41)	Trivial

Abbreviations: WBHL, Women's Baltic Handball League; LMRL, Lithuanian Women's Handball League (Lietuvos Moteru Rankinio Lyga); LMM, linear mixed model, 90%CI, 90 percent confidence interval; ES, effect size; PL, player load; PL. min-1, player load per minute; S-RPE, session rating of perceived exertion; %HR<sub>max</sub>, percentage of maximal heart rate. Note: Match time = the time from the beginning to the end of the match including all stoppages (i.e. time-outs and half time break and in-match stoppages); Actual match time = the time each player spent on court excluding all stoppage time.

This study aimed to investigate the match workload in elite female team handball and to compare the workload elicited in matches with different durations. To the best of our knowledge, this is the first investigation evaluating simultaneously the external (using micro-sensors) and internal match loads in handball and therefore providing a comprehensive picture of the matches' workload demand. Previous investigations focusing on the quantification of the external match load through the use of micro-sensors in elite female team handball adopted PL. min-1 as one of the main indicators of the match intensity [7]. Luteberget and Spencer [7] documented a PL. min-1 of  $8.82 \pm 2.06$  AU including all team handball playing positions (i.e. Wing, Back, Pivot and Goalkeeper), and average values between 9 and 10 AU when considering court players only. These findings seem in line with our results since WBHL and LMRL matches documented  $9.2 \pm 2.1$  AU and  $9.3 \pm 2.1$  AU, respectively. Therefore, these can be considered as reference values of match intensity in elite female team handball when monitoring training sessions. Considering internal match load, the average %HR<sub>max</sub> has been used as one of the main parameters to quantify the physiological demand

in elite female team handball [10, 20]. Previous investigations reported an average of 86% of HR<sub>max</sub> for elite female court handball players with 90% of playing time spent >85% of HR<sub>max</sub> [10, 20]. Similarly, our players reached an average %HR<sub>max</sub> of  $84.2 \pm 6.7$  and  $84.4 \pm 5.1$  in WBHL and LMRL, respectively, highlighting and confirming the high physiological demand in elite team handball matches. Considering the perceived load, while a few investigations have monitored training load in team handball using the S-RPE method [17, 21, 22], to the best of our knowledge, this is the first study using this methodology to quantify match loads. Our results indicate match loads >400 AU in both investigated leagues and call for future investigations in elite female handball to confirm this result. It should also be considered that the quantification of players' workload using S-RPE during training sessions relies on the indication of the training session time, which ranges from the beginning to the end of the session. Differently, when considering the quantification of match time in team sports including both live and stoppage time periods there might be some difficulties in the calculation of match time. In previous basketball investigations [23, 25], match time was

recorded from the start to the end of the match including all stoppages (fouls, out-of-bounds, injuries, time-outs, and inter-quarter breaks). The inclusion of all stoppage time might be a limitation since players are usually resting during these periods and are not actively involved in the matches. Moreover, players usually have different playing and bench time, and this might also influence the quantification of match load from S-RPE. To overcome this limitation, in this study we calculated the match load from S-RPE using both match time and actual match time. Future studies should investigate which of these calculations is the most appropriate in court-based sports including live and stoppage time match periods.

Match duration seems to play a fundamental role in calculating handball players' workload. The LMRL games showed an average of ~ 86 min of match time (including 10-min break between halves and all stoppage times). This match length is similar to that previously reported in elite female team handball international competition, in which the total duration was ~ 72 min excluding the between-half breaks and time-outs [7]. When considering WBHL, which is characterized by matches with a shorter duration (i.e. two 20-min halves), we found a statistically significant shorter match time (64 min), which corresponded to a significantly different actual match time (31 min vs. 37 min). To the best of our knowledge, this is the first study applying this approach, which considers both match time and actual match time in team handball, which seems fundamental considering the nature of this sport, characterized by both live and stoppage time phases.

To date, no previous study has compared the external and internal workload in matches characterized by different lengths. Our findings indicated different results for total PL and PL. min<sup>-1</sup> when comparing LMRL and WBHL matches. As expected, total PL was moderately higher in LMRL matches compared to WBHL matches when considering both match time and actual match time. Indeed, it seems that total PL, which is an indicator of the match volume, is directly affected by the duration of the matches. Conversely, although LMRL entailed a longer match time and actual match time compared to WBHL, no statistically significant differences were found in PL. min<sup>-1</sup>, which is considered an indicator of the match intensity [7]. When comparing the internal match load responses between WBHL and LMRL, similar results were found for %HR<sub>max</sub>, which revealed no statistically significant differences. Conversely, statistically significant differences with small to moderate effect sizes were found for the match load calculated via S-RPE considering both match time and actual time. This finding might be explained by the fact that S-RPE seems strongly dependent on the match duration, which was significantly different between leagues. These inconsistencies of results between and within different internal and external match load measures might indicate that these monitoring approaches measure different constructs. Our findings are supported by a previous investigation, assessing the relationship between internal and external training load methodologies in similar court-based sports such as basketball revealing low commonality with 14–38% of shared

variance between internal and external training load approaches [11]. Indeed, other factors outside of the whole-body movements detected by microsensors might have influenced the internal responses of players during handball matches. Moreover, the differences reported between %HR<sub>max</sub> and S-RPE also question the possible relationship between these two internal load monitoring measures during handball matches. Indeed, to the best of our knowledge, no previous investigation has assessed the relationship between internal and external training load measures and between objective and subjective internal training load measures in team handball, calling for future studies.

Although this study provides interesting information for elite female handball coaches and practitioners, some limitations should be addressed. Firstly, our results refer to only one elite female handball team and only 8 court players were investigated. Secondly, our external load measures refer to total PL and PL. min<sup>-1</sup> only. Therefore, future studies should investigate a larger sample size and monitor match loads using other external load measures such as accelerations, decelerations and changes of direction to provide a more comprehensive picture of the match workload experienced by elite female handball players.

### *Practical applications*

Our findings provide important practical insights for female team handball coaches and practitioners. To reach the match demand during training sessions, players should have approximately a PL. min<sup>-1</sup> of 9 AU, 85% of the HR<sub>max</sub> and a load calculated via S-RPE ~ 400 AU and between ~500 and 630 AU when considering actual and total training time, respectively. Additionally, when planning their weekly training load, elite female handball coaches should consider the matches' durations considering that different match lengths elicit a different match volume (i.e. total PL) and similar match intensity (i.e. PL. min<sup>-1</sup> and %HR<sub>max</sub>).

### **CONCLUSIONS**

The main findings indicate that elite female handball matches require high physical, physiological and perceived demands. Additionally, a longer match time corresponded to dissimilar responses in external and internal match loads. Concerning external load, longer match time determines a significantly higher total PL and a similar PL. min<sup>-1</sup> compared to matches with a shorter duration. The analysis of internal load also indicated contrasting results with between-league differences for match load calculated from S-RPE, while no differences were found for %HR<sub>max</sub>. These results indicate the importance of combining the use of different monitoring match load strategies in team handball.

**Conflict of interests:** the authors declared no conflict of interests regarding the publication of this manuscript.

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