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ORIGINAL SCIENTIFIC PAPER

Monitoring the Internal and External Loads of Young Team Handball Players during Competition

Dora Maric[1,2], Barbara Gilic[1,3], Nikola Foretic[1]

[1]University of Split, Faculty of Kinesiology, Split, Croatia, [2]University of Palermo, PhD Program in Health Promotion and Cognitive Sciences, Palermo, Croatia, [3]University of Zagreb, Faculty of Kinesiology, Zagreb, Croatia

Abstract

This study aimed to examine the internal- and external-training-load (ITL and ETL, respectively) during a match of young handball players. Field testing included heart-rate monitoring (memory belt, Suunto) as a marker of ITL and accelerometry (motion-biosensor, Actical Respironcis, Philips) as a marker of ETL. Time motion analysis data were obtained by recording the player's game activities and later analysed with the Matlab software package. T-test and Pearson-product-moment correlation coefficient were used to examine the differences and the relationship between variables collected in the study. The t-test analysis did not show significant differences between the total distance covered (2216.42–2135.42 m), steps conducted (1829.25–1829.83 steps), steps per minute (91.46–91.49 steps/min), energy expenditure (92.24–90.87 METS), time spent in higher intensity zones calculated by motion biosensor (13.08–12.75 minutes), training-load calculated by Edwards TRIMP method (91.54–88.56 scores) in the first and in the second half of the match. Physical activity variables show no significant correlations with the data assessed by heart rate monitors. Similar results in monitored training-load variables in the first and second halves are connected with the game intensity, which was consistent throughout the match. The lack of correlations between ITL and ETL variables indicates that accelerometry is not suitable for the assessment of metabolic training load in intermittent activities, such as handball. ITL measures used in this study are more suitable for controlling load during training and competition, while the ETL parameters used are more appropriate for better understanding players activity in periods in which the players do not train; other activities can influence players fatigue and training and competition performance.

Keywords: *heart rate, accelerometry, Actical, match, energy expenditure, distance covered*

Introduction

The necessity of the improvement and individualization of training programmes has led to the development of technologies used for monitoring (quantifying) training and match activities (Halson, 2014; Cardinale & Varley, 2017). Successful monitoring of training and match load provides a better image of individual training tolerances, which is affected by numerous factors, such as the player's age, previous experience, fitness level, nutrition, and recovery practices (Coutts, Wallace, & Slattery, 2004; Havolli, Bahtiri, Begu, Ibrani, & Makolli, 2018). Accordingly, the data obtained provide a firm basis for optimal training periodization and consequentially maximizing athletic performance, reducing injury risk, and avoiding overreaching and overtraining syndromes (Soligard et al., 2016; Cardinale & Varley 2017).

In general, the principle of training can be simply displayed as a dose-response relationship between the physiological stress combined with the training load ("dose") and the training adaptations ("response") (Borresen & Lambert, 2009). That being said, it is clear that internal and exter-

Correspondence:

D. Maric
University of Split, Faculty of Kinesiology, Nikole Tesle 6, 21000, Split, Croatia
E-mail: do.maric@gmail.com

nal training loads employ different pathways and thus need to be monitored and analysed complementarily (Lambert & Borresen, 2010). More precisely, the internal training load (ITL) represents the psycho-physiological response by the athlete that primarily takes the form of biochemical stress, and it is usually assessed by heart rate (HR), haematological measures, and perceptual rating of intensity (Williford, Olson, Gauger, Duey, & Blessing, 1998; Scott, et al. 2013). External training load (ETL) represents the activities performed by athletes (i.e., the dose performed) and is measured independently of their internal characteristics, quantified by measuring distance covered speed, acceleration, duration, metabolic power, body load, and sport-specific movements (Williford et al. 1998; Scott, Black, Quinn, & Coutts, 2013).

Handball is an intermittent high-intensity Olympic team sport characterized by specific tactical and physiological demands (Granados, Izquierdo, Ibanez, Ruesta, & Gorostiaga, 2008; Souhail, Castagna, Mohamed, Younes, & Chamari, 2010). Match activity is characterized by a significant number of rapid changes of direction, sideward movements, sprints, jumps, throws, and body-contacts (Buchheit et al., 2009). Therefore, understanding the demands of the game is essential for the design of handball-specific training drills in both professional and developing players (Karcher & Buchheit, 2014; Muratovic & Georgiev, 2012). However, regardless of its popularity (mainly in Europe) research is limited to some extent; more particularly, there is a lack of research examining the specific demands and impact it has on youth players and how they differ from seniors (Foretic, Uljevic, Cardinale, & Spasić, 2018).

That being said, this study aimed to examine the internal and external training load (TL) during the match of young handball players and compare results obtained with systems for assessing ITL (HR) with results obtained with systems for assessing ETL.

Methods

Participants

Twelve young male team handball players, (age: 13.33± 0.57, body height: 168.25 ±12.15 cm, body weight: 57.09±13.31 kg, body fat: 9.33% ±1.19%), regularly training for at least three years, took part in this study. Subjects were all members of the handball club from Split, Croatia, and regular participants in the finals of the Croatian national championship. Because all participants belonged to the same team, they had the same handball training programmes during the three years before the study took place. Participants were asked to attend one laboratory session for the determination of maximal oxygen uptake and two handball games.

Laboratory and field testing

The study was conducted during the competitive season. The participants and their parents were fully informed about testing procedures before participating in the study; informed consent was signed by the parents. The ethics committee of the Faculty of Kinesiology of the University of Split confirmed and approved the study.

Laboratory testing included basic anthropometric measurements and spiroergometry testing during an incremental running protocol on a treadmill. Seven spiroergometry parameters were determined during the treadmill test, and HRmax was used to determine intensity zones during the games and to calculate total training load (TL).

Time-motion analysis data were obtained through the recording of the players' game activities. One video camera (Sony, HDR-XR520V, Tokyo, Japan) was positioned on a tripod 20 m above the team handball court and parallel to the edge of the court (15 m from the touchline), so it could cover the entire field during recording. Match recordings were later replayed and analysed with a bespoke software package developed with Matlab (Mathworks, Natick, USA) to extract time-motion data. Players' movements (distance covered) were measured on the horizontal plane. A specific algorithm was developed in Matlab so that the number of pixels that centre of mass travelled on the screen in any direction represented the true player's distance travelled on the court on the horizontal plane. Velocity was calculated using distance and time data (v=s/t, where v=speed, s=distance, t=time). Manual and semi-automated tracking was used to determine the path for each player. Time was calculated by counting the number of frames between the starting and ending positions of a player's movement (one frame=1/25 of second). Heart rate data were recorded with chest straps (Suunto T6, Vantaa, Finland), which were worn by the players 30 min before the start of the experimental game and removed 30 min after the end. Heart rate-based intensity zones were determined individually by using the results of the spiroergometry test, as a reference, as follows: 50–60 % HRmax (Z1), 60–70 % HRmax (Z2), 70–80 % HRmax (Z3), 80–90 % HRmax (Z4) and 90–100 % HRmax (Z5). The Edwards' Heart Rate–Based Method was used to determine the TL of the game measured. Blood samples were collected at two predetermined time points throughout the matches from the fingertips. The blood samples were immediately placed on strips for analysis in a validated portable lactate analyser (Accutrend; Roche, Mannheim, Germany). The analysis was conducted using six identical lactate analysers. Blood sampling and lactate analysis were conducted by six trained sports scientists. The capillary blood samples were collected after the first half and after the second half of the matches.

The Actical accelerometer was used to gather the following activity data: number of steps, total energy expenditure (TotEE) and time spent in activity zones; it is a small, water-resistant accelerometer (28×27×10 mm, 17 g). It has a multi-directional sensor and is capable of measuring movement in three planes. For the present study, the monitors were initialized to save data in 60-second intervals (epochs) to detect the activities of players. Players wore the accelerometers on the right ankle secured and supported with an elastic belt and kinesio-tape.

Design

The training games used for analysis were organized against two teams that play in the same league as the participants of the study. Before each game, the participants performed a typical warm-up that lasted 15 minutes (3 minutes of dynamic warm-up, 5 minutes passing drills, and 7 minutes situational drills with shots on goal). Each half of the game lasted 20 minutes without stopping time and with a break of five minutes between the two halves as per national league rules for this age group. All participants were playing without rolling substitutions, so each player had to play the whole game of 40 min. The defensive system adopted in both games was a 3:3 formation. Game rules were modified so that the players could not be excluded (power play) from play. This enabled continuity of the situational load during the game.

Statistical analyses

Statistica ver. 12 software was used in the data analysis. The level of significance was set at the alpha level of 0.05. Descriptive data for all the variables are shown as mean and SD. The normality of all variables was tested using the Kolmogorov-Smirnov test procedure. Student's t-test was used to examine the differences between the first and second halves. The Pearson product-moment correlation coefficient was used to assess the relationship between variables collected in the study. Data are presented as mean and SD. Alpha was set at $p<0.05$.

Results

The data on intensity zones showed that the players spent a large percentage of the total playing time in high-intensity heart rate zones (Table 1). Blood lactate measurements conducted at the end of each half of the game reached values below 10 mmol/L, and a significant reduction in blood lactate was evident between the first and the second half of the game. The time-motion analysis did not show significant differences in the total distance covered by players in the first (2220.50±162.85 m) and in the second (2131.42±239.80 m) half of the match. Average speed in the first half (6.17±1.79 km/h) was almost the same as in the second half (6.18±1.96 km/h). There was no difference in the time spent in different time zones between first and second halves, for Edward TRIMP and Actical measurement, respectively. According to the Actical measurement, the number of steps and total energy expenditure was almost the same in the first and the second halves of the match.

Tables 2 and 3 present correlations between variables of internal and variables of external load during the first and second halves of the match. Only one statistically significant correlation was observed: between lactate concentration and total energy expenditure.

Table 1. Differences between First and Second Half of the Match Calculated With T-Test

Variables	1st Half-Time M±SD	2nd Half-Time M±SD
Steps	1829.25±142.61	1829.83±153.14
TotEE (METs)	92.24±5.20	90.87±4.45
Time/vigorous (min)	13.08±4.58	12.75±2.99
Time/moderate (min)	6.92±4.58	7.25±2.99
Distance (m)	2216.42±169.70	2135.42±236.71
Lactate (mmol/L)	6.07±2.13*	4.31±1.19*
Z5 (%)	57.44±27.42	48.05±31.20
Z4 (%)	34.10±23.10	40.51±25.78
Speed (m/s)	6.76±1.09	6.77±1.39

Legend: Steps-number of steps; TotEE-total energy expenditure; Time/vigorous-time spent in vigorous activity zone; Time/moderate- time spent in moderate activity zone; Distance-distance covered; Lactate-blood lactate concentration level: Z5- 90-100 % of maximal HR zone; Z4- 80-90 % of maximal HR zone; Speed- average speed of movement

Table 2. Correlations between Variables of Internal and External Load during - First Half of the Match

Variables	D	AS	Steps	TotEE	Time(mod)	Time(vig)
L	0.50	0.40	-0.05	0.59*	-0.53	0.53
HR	0.23	0.29	-0.25	-0.10	0.11	-0.11
Z5	0.22	0.31	-0.08	0.02	0.10	-0.10
Z4	-0.19	-0.23	0.06	0.07	-0.15	0.15
Z3	-0.17	-0.31	0.03	-0.27	0.20	-0.20

Legend: D-distance covered; L-blood lactate concentration level; Z5-90-100 % of maximal HR zone; Z4-80-90 % of maximal HR zone; Z3-70-80 % of maximal HR zone; AS-average speed of movement

Table 3. Correlations between Variables of Internal and External Load during - Second Half of the Match

Variables	D	AS	Steps	TotEE	Time (mod)	Time (vig)
L	0.54	0.49	0.11	0.37	-0.32	0.32
HR	0.35	0.27	0.15	0.15	-0.08	0.08
Z5	-0.05	0.15	0.13	0.16	-0.12	0.12
Z4	0.17	-0.11	-0.10	-0.10	0.03	-0.03
Z3	-0.43	-0.26	-0.04	-0.18	0.27	-0.27

Discussion

This study has several interesting results: 1) although the second half of the match had decreases (or stagnation) in all measured parameters, the only significant difference was noticed in blood lactate concentration, 2) in the first half of the match, the only significant correlation was observed between lactate concentration and total energy expenditure, 3) there are no correlations between ITL and ETL variables during both halves of the match.

From all parameters of training load used in the study, it is evident that the second half of the match was less demanding than the first one. This change was evident on a statistically significant level only for L concentration. Many authors agree that blood lactate concentration is very sensitive to changes in exercise intensity and duration (Beneke, 2003; Faude, Kindermann, & Meyer, 2009; Beneke, Leithäuser, & Ochentel, 2011). In this research, we observed the same trend. The question is why other load-monitoring systems did not recognize a shift of match intensity. Should we not expect that a decrease of L concentration will be associated with a decrease of HR and energy expenditure (Coutts, Reaburn, & Abt, 2003)? We can only speculate about the reasons, but this underscores the complexity of training load monitoring, specifically in pre-adolescents (Halson, 2014; Murray, 2017).

In the first half of the match, a significant correlation was detected only between lactate concentration and total energy expenditure, which is easily explainable. Lactate levels depend primarily on the intensity of the exercise; accordingly, moderate-to-heavy intensity activities can cause lactate levels to rise rapidly and, if the workload continues, the lactate level may stabilize, decline, or continue to rise, depending on training status and genetic characteristics of the individual (Plowman & Smith, 2013). Furthermore, with regard to total energy expenditure, it is well known that it increases in direct proportion to the increase in exercise intensity (Plowman & Smith, 2013). Thus, given that the tested sample consisted of pre-adolescent players whose energy capacities did not allow them to maintain the same intensity through the second half of the game, we may assume that a drop in intensity has led to a decrease in blood lactate levels; however, this was not the case with the total energy expenditure since the gameplay continued.

Regarding the lack of correlations between ITL and ETL variables during both halves of the match, it is essential to note the fact that ITL and ETL use different pathways; thus, they are measured complementarily. As previously mentioned, EL refers to any external stimulus applied to the athlete, resulting in psychological and physiological responses, which are referred to as “internal load” (Borresen & Lambert, 2009; Halson, 2014). Accordingly, in team sports, the TL is primarily derived from team practices, and EL parameters are collectively defined. Therefore, internal responses to the external load could potentially vary (Svilar & Jukic, 2018). For example, in the present study, the number of steps did not change a lot between the two halves of the match, but the L level did (Figure 1). The only logical conclusion that can be established from given results is that number of steps cannot be a marker of intensity like L is.

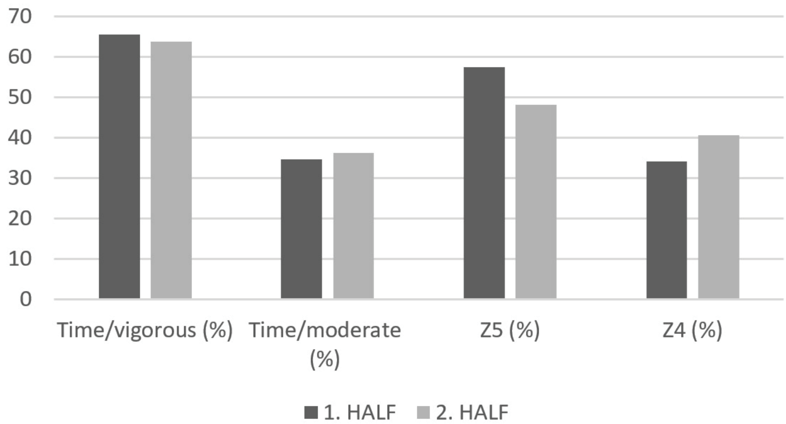

FIGURE 1. Comparison of Accelerometry and Edward’s TRIMP Zones in 1st and 2nd halves of the match

In contrast, according to the accelerometry data, we can say that pre-adolescent handball players are very active since they spend the majority of their time in the zone of vigorous activity. Thus, the lack of correlations between ITL and ETL in pre-adolescent handball players in competitive conditions is not atypical (Borresen & Lambert, 2009; Akubat, Patel, Barrett, & Abt, 2012). On the contrary, it is simply a confirmation of current attitudes in this area of research that ITL and ETL should be used in different contexts of measurement (Halson, 2014).

Monitoring the training load of young athletes is very important for coaches when designing appropriate training programmes. Data from the competition are of even greater importance, especially in sports like handball, which induce

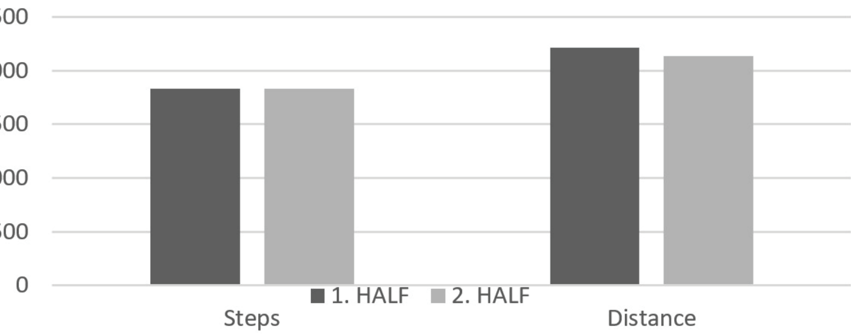

FIGURE 2. Comparison of Step Number and Distance Covered in 1st and 2nd halves of the match

strong physical and psychological responses. From this study, it is evident that in handball, different systems of monitoring produce different data, and these should not be considered in the same context. These differences are mostly seen in lack of correlations between ITL and ETL parameters (Figure 2).

It should be noted that accelerometers have many advantages, but they also have some limitations. The most problematic limitation is the inability of measuring the intensity of physical activity, which was observed in our study. One example is the cumulative number of steps (or volume of activity) taken during a bout of activity. This data offers no information regarding the intensity at which those steps were accumulated. Accordingly, in pre-adolescent handball players, during competition, blood lactate concentration and HR should be used as a measure of intensity while kinematic, and accelerometry data should be used as a measure of activity volume. Results of the study may be helpful for handball coaches who work with pre-adolescent handball players. It can help them to choose the correct method of training and competition load measurement. All cited authors think that ITL measures used in this study are more suitable for controlling load during training and competition. At the same time, ETL measures can help coaches better understand players' activity when the latter do not train (i.e., when they are at home or school) and other activities that can influence players fatigue and training and competition performance.

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Conflict of Interest
The authors declare the absence of conflict of interest.

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