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THEORETICAL BASES AND USABILITY OF FIELD TESTS FOR MEASURING THE SPECIFIC AEROBIC ENDURANCE OF HANDBALL PLAYERS

Abstract

Investigating a model that includes shares of different energy mechanisms at loads that characterise handball play provides a basis for suitable fitness training. The handball player’s specific aerobic endurance is distinctive because of the nature of handball play and its duration. Measuring such endurance gives important foundations for the planning of related practice. In the article we describe different possibilities and measurement procedures that we summarise based on the available literature. We seek to follow developmental tendencies in this field over a longer time period. We list recommendations for selecting optimal measurement solutions. We also present the main possibilities for more accurate and controlled training starting with the testing results.

Key words: team handball, testing, specific endurance

Introduction

In handball, the intensity and range of loadings on players vary considerably. Alongside cyclic movements (running, walking), acyclic activities also occur during a handball game, including: passing, shooting, jumping and landing, physical contact with the opponent in a struggle for the ball, falling and rising off the floor as well as faking and penetrating (Šibila, 2004). Therefore, loadings in handball combine both cyclic and acyclic activities. These loadings occur at intervals. This means that during a game loadings of a high or low intensity and of a large or small range constantly alternate with relative and temporally variable periods of rest which is defined as the time a player stands on the spot or walks (Cambel, 1985; Sichelschmid & Klein, 1986; Martin, 1990; Kuchenbecker & Zieschang, 1992; Bon, 2001). The loading on handball players also depends on the type of the zone defence and the players’ roles in the game (Pori, 2003). Acyclic activities are usually performed at a high intensity and account for the bulk of player’s loading. Highly intensive runs (sprints) are therefore only one part of the highly intensive loadings on handball players. The range of less intensive cyclic
activities or standing on the spot, without any additional acyclic loading, is defined as the period of rest between highly intensive loadings of the cyclic and acyclic types. The game thus consists of specific phases during which the player is exposed to a high loading and phases during which the loading is relatively lower (Šibila, Bravničar, Pori, & Bon, 1999). Handball-specific loadings can be one-off, but many times they occur in successive repetitions and last generally from 5s to 30s. This triggers very intensive metabolic processes of a predominantly anaerobic type. During interruptions oxidative energy processes prevail (Rannou, Prioux, Zouhal, & Gratas-Delamarche, 2001; Böttcher, 1998). The stronger the demands for a greater frequency of the high-low loading cycle during a match and the shorter the period of rest within this cycle, the more important is good specific endurance. This fact is gaining ground in the modern model of the handball game. Similar findings have been reported in some related sports such as football (Bangsbo & Michalsik, 2002; Reilly, 2003; Stroyer, Hansen, & Klausen, 2004), basketball (Mc Innes, Carlson, Jones, & McKenna, 1995), rugby (Docherty, Wenger, & Neary 1988; Deutsch, Maw, Jenkins, & Reaburn, 1988), ice hockey (Cox, Miles, Verde, & Rhodes, 1995) and grass hockey (Lemmink & Visscher, 2006). Thus, in recent times high-intensity interval training is often applied in sports (Buchheit, Laursen, Millet, Pactat, & Ahmaidi, 2008), but it focuses on the concomitant development of aerobic and anaerobic capacity (Billat, 2001). Mechanisms such as fast cardiovascular kinetics or high-speed kinetics of muscle substrate restoration (re-oxidation of myoglobin and haemoglobin as well as phosphocreatine restoration) (Millet, Candau, Fattori, Bignet, & Varray, 2003) can enhance the role of oxygen and help preserve anaerobic capacities. This enhances the ability to repeat highly intensive interval loadings (Buchheit, Laursen, Millet, Pactat, & Ahmaidi, 2008). One must also consider the basic characteristics of interval training which directly influence the time during which the performance of interval exercises results in exhaustion – the intensity and duration of loading as well as the duration and potential intensity of activities performed during a period of rest (Billat, 2001; Morton & Billat, 2004).

**Handball players’ endurance**

Sports endurance can be defined as follows: endurance is a complex motor-fitness ability to withstand a specific sport loading over a maximum time period and/or restore this ability within the shortest time possible after a sport (psycho-physical) loading (Grosser, Starischka, & Zimmermann, 1998). Endurance is therefore a very important ability in sport as it prolongs
the duration of a loading and accelerates the restoration of the ability required to withstand subsequent sport loadings. The purpose of the introduction was to explain that the endurance-motor requirements of handball include the development of general aerobic and specific anaerobic preparations. As regards aerobic endurance, data on the maximal aerobic power (MAP) of handball players are very important. Maximal aerobic power is not the most critical factor in a handball game (like in some athletic disciplines or cross-country skiing and similar ‘endurance’ sports); however, it is relatively important mainly due to the intertwining impact of all three metabolic mechanisms (Wallace & Cardinale, 1997; Cardinale & Manzi, 2008). The available literature reveals that a higher level of aerobic power was measured in athletes dedicated to sprinting compared to the normal population (Thoden, 1991). Maximal aerobic power is the maximal quantity of oxygen the body can extract from the atmosphere and then transport and use in tissues. In terms of quantity, it is equivalent to the maximum volume of oxygen a person can consume per time unit when a loading is exerted on a large muscle group with a progressive intensity and continues until exhaustion. The oxygen consumption is expressed as the maximum (max) volume (V) of oxygen (O_2) consumed per minute (VO_2max). It is generally presented and explained in absolute terms (absolute volume per minute – L/min) or as a relative value in terms of body weight (ml/kg/min) (Thoden, 1991). Maximal aerobic power reflects both the body’s ability to transport O_2 and the muscles’ ability to consume it. In measurements, its value depends on the method of performing the test and on the involvement of specific muscles and muscle groups. Therefore, the relevance of the maximal aerobic power measurement depends on how the test is conducted (Thoden, 1991). If a measurement is to have a practical value, the test protocol must include activities which represent athletes’ actual loadings in individual sports. It is recommended that the test is performed in similar circumstances to those seen during a match. Therefore, in handball it is optimal that the tests are performed on a handball court. The measurement process is often hindered by some technical limitations; however, the advantages of this approach mostly compensate for the technical difficulties.

**Field test protocols for assessing the level of handball players’ aerobic endurance**

The development of test protocols for assessing endurance was based on knowledge of loadings exerted on handball players during a match, as described in the introduction, and the
related energy requirements. In this respect, handball is similar to some other sports and therefore the test protocols most often used are those developed for different sports.

Field test protocols for assessing the level of handball players’ aerobic endurance can be of the continuous or interval type. They are performed in various measurement conditions – mainly on an athletic track or in a handball hall. The subjects run without changing direction (running straight along an athletic track, running straight along the edge of a sports hall) or with changes in direction on a polygon, e.g. on a handball court. Several tests have been developed where players also perform some technical handball elements while running.

One of the first tests to be used to assess players’ endurance was Cooper’s test. It is the most widely known and used test for establishing aerobic endurance in both recreational and competitive sports. Players performing this test must run the longest distance possible in 12 minutes or run 2,400m within the shortest time possible. For those competing in different sports (basketball and football) norms have been defined on a five- or six-degree scale, including a descriptive assessment of a person’s achievement in terms of the distance covered (Steinhöfer, 1996; Weineck, 1998; Hagedorn & Meseck, 1985). They are based on modified original values defined by Cooper (Cooper, 1968) and are also applicable to handball players. In recent times, this test has been used less and less since the results yielded insufficient concrete information on handball players’ specific endurance levels. The results obtained did not facilitate the detailed planning of endurance training.

More sophisticated field tests are based on the acceleration of running velocity in specific time intervals which the subjects perform until exhaustion. Thus the final velocity at which the players were still able to run is established. Conconi’s test (Conconi, Ferrari, Ziglio, Droghetti, & Codeca, 1982) is of this type and is also performed in a handball hall. The test is based on a changing running velocity which gradually increases after a player has covered a distance of 200m. The increase in the heart rate is measured during the test loading and serves as a basic physiological indicator. For subsequent procedures in which data are used for various purposes, important information included data on the maximum heart rate recorded. Together with data on the heart rate during rest it is used to establish the so-called heart rate reserve. The latter is used to define classes which describe the degree of strain under a specific loading exerted on a player during a match (Bon, 2001; Pori, 2003). This test is also used to establish the anaerobic or lactate threshold of an individual athlete. At the beginning
of the test (running at a slower pace) the ratio between the increase in the velocity of running and the increase in the heart rate is nearly linear. The ever higher running velocity reaches the point where it increases faster than the heart rate. According to Conconi, the anaerobic threshold can be found at the point where the straight line characteristically turns into a gentler curve (deflexion). The velocity at which the subject reaches the abovementioned point is also very interesting for the planning of endurance training. Erčulj (2001) used a slightly modified Conconi test to establish the anaerobic threshold of basketball players. The subjects performed the test in two ways, either running a distance of 20 m with changes in direction or running along the edge of a sports hall (following an elliptical shape) – each ellipse was 70m long. The running velocity gradually increased according to sound signals dictating the running pace to the runners. He established that the subjects achieved a higher average and maximum pulse in the test involving changes in direction. In this test, the pulse at the calculated anaerobic threshold was higher and so was the blood lactate value after the test was completed. When running along the edge of a sports hall a higher velocity was recorded at the anaerobic threshold. Based on these results, he concluded that it was difficult to unequivocally assert which of the two tests was more appropriate for establishing the anaerobic threshold. He therefore proposed that the results of both tests be compared to those obtained from some other tests where different criteria were applied to establish the anaerobic threshold. Of course, in Conconi’s test the loading indicators can also be monitored using ergospirometry and thus data on VO_{2\text{max}} can be obtained.

Despite these adjustments, the abovementioned Cooper and Conconi tests have shown certain deficiencies in terms of measuring aerobic endurance: they were both of the continuous type which is contrary to the interval character of handball players’ loadings; the way of moving is not directly related to the handball game where stopping (deceleration) and acceleration occur (Šibila, 2002).

For this reason researchers have tried to develop field test protocols to measure aerobic endurance (maximal aerobic power) whereby these deficiencies can be eliminated and the movement structure typical of sports games can be better simulated. More specific movements in the test should enhance their validity (Balsom, 1994; MacDougall & Wenger, 1991). One of the first such tests was Leger’s multistage fitness test (20-m MMSRT) (Leger & Lambert, 1982) where the subjects ran 20 m distances with changes in direction on an adapted polygon. The test was of the continuous type, the initial running velocity of 8.5 km•h$^{-1}$
was low and increased by 0.5 km•h⁻¹ with each successive stage. The running pace was dictated by a sound signal. Later on, the test was slightly modified (Leger, Mercier, Gadoury, & Lambert, 1988) and validated (Ramsbottom, Brewer, & Williams, 1988). The above authors used the test results to calculate the assessed VO₂max which should be based on a regression equation derived from the ratio between the VO₂max and maximal final velocity recorded in the last successfully performed repetition. They established a high correlation between the VO₂max measured directly on a laboratory treadmill and the assessed VO₂max obtained in a field test (r=0.92) (Ramsbottom, Brewer, & Williams, 1988). A similar result (r=0.93) was also reported by Paliczka, Nichols and Boreham (1987). In view of their results, the discrepancy between the measured and assessed values should not exceed 3.5 ml•kg⁻¹•min⁻¹. This approach to test validation was immediately criticised in terms of methodology (Hopkins, Hawley, & Burke, 1999). Sproule, Kunalan, McNeil and Wright (1993) established that for 75% of subjects the VO₂max assessed using a field test was lower than that measured in a laboratory. Similar results were also reported by St. Clair-Gibson, Broomhead, Lambert and Hawley (1998): in Leger’s 20 m test the assessed VO₂max of squash players and runners was 61 ml•kg⁻¹•min⁻¹ on average, whereas on the treadmill it averaged 66.5 ml•kg⁻¹•min⁻¹. Irrespective of all of the abovementioned problems the test was often used to measure the aerobic endurance of football players of the British football league (Davis, Brewer, & Atkin, 1992; Strudwick, Reilly, & Doran, 2002) and of members of the Australian Olympic Team (Tumilty, 2000). Unfortunately, the test could not satisfy the expectations of researchers and coaches. Namely, researchers established that it was insufficiently sensitive for investigating changes in the endurance of those athletes in sport games who had undergone a specific training process. Moreover, using this test it was difficult to distinguish between players of lesser and greater quality. Odetoyinbo and Ramsbottom (1997) established no significant progress in the results achieved in 20 m MMSRT in those football players who had undergone an eight-week highly intensive training involving running. The differences between young professional football players and those at a recreational quality level were also insignificant (Edwards, MacFayden, & Clark, 2003). Svensson and Drust (2005) estimated that the mentioned deficiencies could stem from the way the test was performed as it does not represent the actual requirements of sports games characterised by interval loadings. Similar findings were also reported by Lemmink, Verheijen and Visscher (2004). By all means, the test has served as a basis for developing even more sophisticated field test protocols.
Thus the Yo-Yo IR (Intermittent Recovery) test was designed and is one of the most widely used interval tests (Bangsbo, 1994). It has been relatively extensively used in sports games (Bangsbo, 1996a; Bangsbo, 1996b). It consists of repeated running sessions whose velocity rises progressively with each repetition – each session equals 2 x 20 m. The subject starts on the start line, runs to a line on the other side of the area, turns around and runs back. Between one run and the next there is a 10s active break (slow running – 2 x 5m). The running velocity (pace) is dictated by a sound signal. The subject performs the test until exhaustion and/or until the moment they can no longer keep pace with the growing running velocity (i.e. when they fail to reach a specific line according to the sound signal on two consecutive occasions). In view of the different measurement subjects two types or levels of the test have been developed: Yo-Yo IR1 and Yo-Yo IR2. With the first type the subjects start running at a low velocity which increases slower than with the second type. Therefore, the measurements using the Yo-Yo IR1 test focus on assessing the ability to perform interval loadings which cause maximal activation of the aerobic system. The Yo-Yo IR2 test is used to define a person’s ability to recover their capacity after repeated loadings with a strong involvement of the anaerobic system. Measurements of athletes in different sport games show that athletes of higher quality (better performing) achieve higher results in the Yo-Yo tests (Mohr, Krustup, & Bangsbo, 2003; Thomas, Dawson, & Goodman, 2006; Castagna, Abt, & D’Ottavio, 2007; Sirotic & Coutts, 2007). Results of the discussed test also show greater sensitivity to changes in competitive performance compared to VO2max alone. Therefore, the Yo-Yo IR test offers a simple and valid possibility for assessing someone’s ability to repeat intensive loadings and for investigating changes in an athlete’s capacity in sport games (Bangsbo, Iaia, & Krustup, 2008; Castagna, Impellizzeri, Rampini, D’Ottavio, & Manzi, 2008). This test also requires the use of ergospirometry for a more accurate assessment of aerobic capacity (Metaxas, Koutlifanos, Kouidi, & Deligiannis, 2005).

Similar to this test is the so-called Interval Shuttle Run Test (‘ISRT’) (Lemmink, 2000). This test also involves running (30s) with interruptions and increasing velocity with every repetition, whereas between these repetitions there are active 15s breaks during which the subject walks. The track is 20 m long (Figure 1), the running pace is dictated by a sound signal and the test is performed until exhaustion. It is intended to measure endurance under sub-maximal and maximal loadings with interruptions. The initial running velocity is 10 km•h⁻¹ and increases every 90 s. It rises by 1 km•h⁻¹ until it reaches 13 km•h⁻¹, then it increases by 0.5 km•h⁻¹. Researchers have established a high level of discriminant power of
the test when distinguishing between football players of different quality categories (Lemmink, Verheijen, & Visscher, 2004). They have also established a very high level of reliability of the test and evaluated it as adequate for assessing the specific endurance of players in sports games (Lemmink, Visscher, Lambert, & Lamberts, 2004).

Figure 1: Polygon for the ISRT test

The Yo-Yo and ISRT tests mark considerable progress in field measurements of players’ endurance in sports games. They are both of the interval type and the movement is performed with changes in direction (acceleration and deceleration) on the court, which is why the assessment of a player’s capacity in terms of their endurance is obtained in conditions which actually more closely resemble players’ loadings during sport games. However, even based on these results it is difficult to dose loading in handball players’ interval training.

In terms of the level of precision of the test and its versatility, the most interesting test for handball is the so-called 30-15IFT (30-15 Intermittent Fitness Test) (Buchheit, 2005a; Buchheit, 2005b). It is tailored to the needs of handball players and performed on a handball court, using the lines (markings) on the court. The test consists of 30s runs and 15s rests, the latter can be either walking or standing on the spot. The running velocity (loading) increases with each repetition and the subjects perform the test until exhaustion and/or until they can cope with the increasing loading. The running velocity (pace) is dictated by a sound signal.
according to which the subjects orient themselves as it resounds at the beginning of every 30s of loading, at every line on the handball court (thus informing the subjects whether they are lagging behind or running ahead of the required velocity and can therefore accelerate or decelerate) and at the end of every 30s of loading. The sound signals differ accordingly. The initial velocity is 8 km/h and grows by 0.5 km/h with every repetition. The subjects run for as long as they are able to keep up with the velocity dictated by the sound signals. The test is completed when they are unable to reach the selected line on the court three consecutive times (or 3m of the tolerance zone in front of the line). The final result is the last velocity which the subject ran in accordance with the described rules. The author named this velocity Maximal Aerobic Velocity or MAV. This term has already been used in professional literature (Billat, Koralsztein, 1996). To facilitate orientation, the lines on the handball court (both transversal lines and the central one) were named ‘A’ (the transversal line where the first start is), ‘B’ (central line) and ‘C’ (the second transversal line). Adjacent to each line is a marked three-metre tolerance zone (Figure 2). During the test protocol the subjects wear heart rate monitors measuring changes in the heart rate due to the increasing loading. If feasible, it is recommended that a blood sample be taken during each period of rest so as to analyse the blood lactate values. In optimal conditions (mainly for the purpose of scientific research) ergospirometry can also be applied. The test can be performed by several players at a time, although in practice it is optimal if there are only 4 to 6 players on the court at a time so as to ensure better control over the subjects. The obtained result enables the approximate maximum use of oxygen to be calculated using the following formula: 

$$VO_{2max}(ml/min/kg) = 28.3 - 2.15 * G - 0.741 * A - 0.0357 * P + 0.0586 * A * V + 1.03 * V, \text{ where: G is gender (1 = male, 3 = female), A is age, P is weight and V is the final velocity recorded in the test (MAV).}$$
Tests also involving handball technique elements

Concurrently, some specific handball tests have been developed in which subjects imitate even more intensively the loadings typical of a handball game. In these tests, the subjects perform acyclic contents (technical elements) during cyclic activities (running). The literature includes some interesting researches where the authors applied the abovementioned measurement method to assess handball players’ endurance levels. Some of the most interesting ones are presented below.

During preparations for the 1997 Women’s World Handball Championship in Germany, measurements were performed to assess the endurance and sprinting abilities of 18 female members of the German National Team (Brings, Platen, & Hoffmann, 1998). They performed 5 sprints of 30m and interim results were measured at 5, 10 and 20 metres. A one-minute break took place between the sprints. Two tests were performed to assess aerobic endurance. The first was a field test performed on a 400m tartan track with increasing intensity until exhaustion. The initial velocity was 2.5 m/s and was increased by 0.5 m/s. A one-minute break took place between individual stages of the loading. The pace of the run was dictated by a sound signal every 50 metres. The second test for assessing endurance was a handball-specific test with rising velocity and was performed in a handball hall. The length of the specially designed polygon was 70m. The female subjects had to run zigzag while dribbling the ball. The initial velocity was 2.0 m/s and was increased by 0.2 m/s until the subjects’ exhaustion. In the field test, an individual loading stage lasted substantially longer than in the specific handball test. The results showed that the running velocity at the anaerobic threshold (4 mmol/l) in both tests does not differ statistically significantly (3.26 ± 0.37 m/s recorded in the handball-specific tests vs. 3.23± 0.34 m/s recorded in the field test). Given the findings of some researchers that the duration of an individual stage of loading in graduated tests also affects the achieved stage of loading at the anaerobic threshold (4 mmol/l of blood lactate).
(Heck, 1990), slightly different results were expected. According to these findings a shorter duration of an individual stage of loading increases the runners’ velocity at 4 mmol/l. As individual stages of loading lasted longer in the field test, it was expected that the female subjects would achieve a higher running velocity at the anaerobic threshold in the handball-specific test. Evidently, the effect of the specific loading associated with ball dribbling and changes in direction while running compensated for the shorter time of an individual velocity stage. However, the subjects achieved a statistically significantly higher maximal (final) velocity in the field test ($3.81 \pm 0.31$ m/s vs. $3.72 \pm 0.34$ m/s). The maximum blood lactate value was on average higher in the field test ($8.9 \pm 1.8$ mmol/l vs. $7.8 \pm 1.4$ mmol/l). The authors ascribed this to the fact that, at a higher velocity, the measured subjects had more coordination difficulties with ball dribbling and finished the test before they had achieved their physiological maximum. However, those test subjects who mastered the ball dribbling technique achieved higher values in the handball-specific test. To dose the training more accurately, the authors recommend using both criteria. In planning the development of handball players’ endurance using exercises where the players have to run and at the same time dribble the ball slightly lower values should be used than for running without any additional exercises. In the conclusion, the authors critically asked whether the handball-specific test they used really did reflect the specifics of the handball game. Dribbling of the ball while running is only one of the elements of the handball game and even this is performed only to some extent.

An interesting method for measuring the specific endurance of handball players using a field test which also consists of technical elements of the handball game (acyclic activities) is the handball-specific endurance test (Kuchenbecker, Zieschang, 1998). The loading in this test is interval-based of the cyclic and acyclic types. The intensity of the activity varies from very low to very high. The activities follow one another in a similar sequence as is typical during a game. The test lasts for 15 minutes and is designed as a polygon on a handball court. One round of the polygon takes 1 minute. Each activity must be performed within a predefined time in accordance with a sound signal. Unfortunately, due to the shortness of the experiment the authors found no statistically significant relationship between the physiological indicators obtained in the test and during the game. The only applicable data they obtained was the statistically significant decrease in the subjects’ blood lactate and heart rate at the end of the preparation period compared to the initial condition. The test consists of specific handball
activities but its validity is questionable as its methodological design – there is no graduation of loading and concurrent measurement of physiological indicators which accompany such a loading. There is no possibility to accurately define the degree of development of specific handball endurance.

Also interesting is research (Leyk, Schirrmacher, Hoffmann, & Baum, 2000) where the authors compared the results of a test designed for assessing endurance, which should reflect the specificity of running in handball, with a classical treadmill test. The sample of subjects consisted of 18 handball players and nine sprinters and long-distance runners. The specific test consisted of short (3m) sprints forwards, sideways and backwards (the total distance of the polygon was 24m). The subjects had to perform three repetitions within one series as fast as possible (72m). After each series there was a break of 30s and 60s, respectively. The test comprised 5 series (360m). The authors found no close correlation between the results of the specific test and those of the treadmill test. They assessed that the specific test was better adapted to the needs of handball players. The repetition of the intervals and duration of the break statistically significantly affected the results only of handball players and sprinters. This means that, with each repetition, the subjects in the two abovementioned groups recorded a poorer time at the 30s break. With long-distance runners the duration of the break did not affect their results in each repetition – the results were constant. The loading in the specific test also influenced the heart rate and blood lactate values. For sprinters and handball players the abovementioned values were substantially higher than for long-distance runners. In all three groups, the blood lactate values in the test with a shorter break between the repetitions were statistically significantly higher than in the test with a longer break. In the treadmill test the long-distance runners recorded a higher final velocity at the end of the test compared to the sprinters and handball players. There were no differences between both tests in terms of the heart rate in all groups of subjects. However, the handball players and sprinters recorded statistically significantly higher blood lactate values for both types of specific test compared to the treadmill test. With the long-distance runners this only occurred in the test with a shorter break. The authors concluded that the specific test provided a lot of important information to handball players which can only be obtained under loadings typical of handball. The characteristics of the running and the duration of the break between individual repetitions must be as similar as possible to the actual loadings in handball. The correctness of their assertions was also proven by the classification of handball players according to the final
results of both tests. The specific test distinguishes players by their playing quality more efficiently than the other test.

**Possibilities for determining running velocity or pace in handball players’ training based on test results (dosing of the range and intensity of loading by running)**

The relatively small level of interest of coaches in testing handball players’ endurance is mainly due to the low degree of usability of test results and their applied value in the planning of conditioning training. Until recently the interpretation of test results on a handball player’s endurance was completed with a simple report indicating a higher or lower level of endurance. Mostly a comment was added recommending that endurance should improve. Unfortunately, there has been a paucity of in-depth analyses of results offering instructions for adequate training which can help improve the examined abilities. This has mainly been due to the deficient laboratory and field tests which have inadequately imitated the specificity of loadings typical of a handball game. In many handball trainings, the practice of training players’ specific endurance levels was at a low level. In handball training a run can be of a continuous or interval type. In a continuous run of a longer duration the setting of the running velocity to optimally develop aerobic power is slightly easier. One can use the so-called direct methods: index endurance and critical power or critical velocity, and indirect methods: velocity at lactate threshold, ventilation threshold and threshold defined on the basis of the heart rate (Bosquet, Leger, & Legros, 2002). However, due to a lack of unambiguous criteria for defining the running intensity and duration difficulties can also occur when defining the intensity and duration of continuous running of a longer duration (Bosquet, Leger, & Legros, 2002). In view of the recent findings and the nature of training, handball coaches are increasingly using high-intensity interval running (Cometti, 2001; Quintallet, 2003). This is also in accordance with findings that highly intensive interval training improves VO_{2max} more than continuous training of a longer duration at a moderate velocity (Helgerud, Høydal, Wang, Karlsen, Berg, Bjerkaas, Simonsen, Helgesen, Hjorth, Bach, & Hoff, 2007). With this type of loading, the setting of the optimal running loading or velocity is even more demanding. Buchheit (Buchheit, 2005) recommends that the basis for calculating the loading with interval runs be the maximal velocity (MAV) achieved at the end of the 30-15_{IFT} test. Together with his co-authors (Buchheit, Laursen, Millet, Pactat, & Ahmaidi, 2008), he also compared the possibility of predicting the players’ capacity in interval runs using the
calculated critical velocity or endurance index. They established that the endurance index was more appropriate for assessing the dosing of interval training. For the purpose of calculation they replaced %VO$_{2\text{max}}$ with % MAV. The results also showed that at a similar running velocity the time until exhaustion is characteristically longer in runs including a 15s loading and a 15s rest compared to the 30/30 interval. This finding is also congruent with findings showing that in the determination of metabolic response in interval training the duration of the loading is more important than the duration of the rest (Ästrand, Åstrand, Christensen, & Hedman, 1960). In the 30/30 interval, more lactate accumulated in the blood based on which it was concluded that the share of anaerobic sources was larger than in the 15/15 interval. Similar practical instructions were also provided by some other authors. Dupont, Blondel, Lensel and Berthoin (2002) recommend 15s interval runs at an intensity equalling 120% of MAV, interrupted by a 15s rest. They believe that supramaximal loading compared to the submaximal one enables the recruitment of muscle fibres in a more specific way, thus facilitating a more specific adaptation. A study of the use of specific playing forms and ball handling exercises in football is very interesting for specific aerobic training in sports games (Hoff, Wisloff, Engen, Kemi, & Helgerud, 2002). The authors established that – provided they are underpinned by good organisation and suitable contents – specific football exercises can be of great use in interval training. Similar views are also presented in a study of special conditioning training in handball (Cardinale & Manzi, 2008). To optimise handball training, the authors recommend a good understanding of the metabolic requirements of specific handball exercises and a right balance between the intensity and range of their performance in various parts of the competitive season.

**Conclusion**

Most of the researchers cited above believe that the measurement of the specific aerobic endurance of handball players (and, generally, athletes in comparable sports) must be based on specific requirements of the handball game. Therefore, the use of field tests with interruptions and changes in direction of movement on the handball court is recommended. Such tests have been developing over several decades and have reached a level enabling a relatively accurate assessment of a handball player’s specific aerobic preparedness. A particularly interesting test for handball players is the 30-15IFT test which is described above. The results of the test serve as a solid basis for the dosing of handball players’ interval training using direct and indirect methods. The use of continuous tests involving straight runs
is a less appropriate method for assessing the specific aerobic endurance of a handball player. Those tests which contain technical elements of handball play are not thoroughly investigated, while their reliability and validity are inferior which is why they cannot be used broadly in handball practice. An important conclusion of this article is that measurement results should be used more efficiently to dose loading more accurately and, consequently, to optimally develop the specific aerobic endurance of handball players. Therefore, the article offers some starting points for an exploration of these connections.

References:


