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CONTENTS

HALF SEASON CHANGES IN PHYSICAL FITNESS FOR THE HIGH LEVEL HANDBALL PLAYERS

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(Original scientific paper)

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Abstract:
To examine the characteristics and changes in physical fitness (PF) during the half-season period in advanced male handball players (MHP). 32 MHP (National 1st division players) served as the subjects. Herein we observed six morphological (M), two cardiovascular–endurance and six motor-status variables at the beginning (I), at the end of the half-season period (II), and at the end of the competition half-season (III). The differences between I, II and III were analyzed by an analysis of the variance (ANOVA). ANOVA showed significant I-to-II increases ($p<0.05$) in: cardiovascular endurance, agility and explosive-strength, while most of the measured variables remained unchanged from II-to-III. The pre-competition period led to significant improvements in most of the observed motor and endurance variables, regardless of high fitness level of the subjects. Meanwhile, no significant changes were found in M status supporting the considerations that substantial M changes are usually unexpected in mature, well-trained athletes.

Key words: *team-sport, motor-endurance status, specific tests, physical conditioning*

INTRODUCTION

Limited information is available concerning the physical fitness (PF) status of elite handball players, especially bearing in mind the constant progress in game-dynamics and consequently – the unavoidable requirements in upgrading the PF profile (e.g. motor, endurance and morphological status) of athletes, especially after 2002 and changes in rules of handball game (e.g. after a goal has been scored, the referee restarts the game as soon as an attacking player is at the centre line and holds the ball). Precisely, scientific interest in studying PF in handball is observable, but it is very rare to find such studies where authors sampled the subjects of the non-questionable quality and/or measured the variables of high pragmatic validity and applicability in handball sport. Of course, such problems (e.g. the subjects and variables) are reasonable bearing in mind that: (a) handball players are mostly professionals, and (b) it is very hard to find a sample of equal quality in the same geographic location at the same time. Therefore, (a) athletes, but even more – their coaches, do not of the approve relatively complicated, time consuming and physically demanding fitness testing procedures, and (b) if such a condition is even met – scientists have a problem to assemble the appropriate number of subjects and to achieve statistical significance in the interpretation of the results. It is evident from the recent studies performed on female handball athletes[1-4].

A one-year, or a one-season period for league sports can be divided into two half-season periods. Both, the first and second half-season consist of the pre-season (pre-competition; Pre-C) and the competition period. In professional handball (also known as team-handball), the Pre-C period in the first half season can be considered as "the main preparation period", because of its longer duration (6-9 weeks), compared to the one in the second half-season (3-4 weeks). During the Pre-C, the characteristic training programmes are done, primarily aimed to improving the basic and specific motor and endurance capacities of the athletes (e.g. physical conditioning). As the competitive season approaches, specific training is increased. In the competition period (the competitive season), the high-level handball teams play two, or even three official games a week. It is generally accepted that competition efficacy is highly dependent on PF status, which means that a high competitive level can not be achieved without the appropriate mor-

phological and proper motor and endurance status level, almost exclusively obtainable during the preseason period [5-7].

Apart from the studies that have observed and investigated some health-related problems, and specific training programmes in handball [8-9], as far as the authors of this paper know, the determination of PF changes dynamics, during the half-season period, is rarely registered in advanced male handball players. Furthermore, it is still not known whether fitness gains attainable during the Pre-C period can be successfully maintained over the duration of the competition season.

Consequently, the aims of this study were:

to define the PF profile in advanced male handball players (MHP)

to define the changes in the PF profiles in MHP, during the half-season period separately for the Pre-C and competition period

MATERIALS AND METHODS

Subjects: Originally, thirty two MHP from two Croatian advanced handball teams, each consisting of sixteen players were used as the sample. Throughout the investigated periods, all the subjects took part in the National League, National Cup and International Handball Federation (IHF) Cup (second most superior European handball Cup) at almost equal dynamics.

Variables: The morphological variables included: body height (BH), body weight (BW), triceps skinfold (TrSF), subscapular skinfold (SSSF), abdominal skinfold (AbSF), thigh skinfold (ThSF), calf skindfold (CaSF), spinailiaca skinfold (SISF), hand span (HS), arm span (AS), calculated body fat percentage (BF%) and lean body mass (LBM). The BW was measured by a digital scale wearing shorts and no shoes (on 0.1 kg), BH was measured using a measuring scale fixed on to the wall at maximum inspiration (to the nearest 0.5 cm), circumferences and spans were measured by measuring tape, ruler and anthropometer, and the skinfolds using the Lange calliper. BF% was calculated using the formula: BF% = (TrSF + SSSF + AbSF + ThSF + CaSF + SISF) x 0.1051 + 2.585; and LBM = BW – Fat Body Mass (Fat body mass = BW x BF%)[10].

The cardiovascular – endurance status was determined using the maximal multi-level 20-meters shuttle run endurance test (SR20M). In brief, the SR20M test was measured in a group of six athletes in a handball gym (wooden floor), using the CD player for the reproduction of the running-tempo sound signals (the number of consecutive levels-plus-sub-levels was noted). The motor variables were as follows: Flexibility - sit and reach (S&R) and maximal shoulder circumduction (SC); Power – countermovement jump test (CMJ), and alternate leg triple jump test (TJ); Agility - hexagon test (HEX) and 20 m agility test (A20M). Briefly, the S&R test is measured as maximal over-toes reach distance from the sitting position, with legs fully straighten at the knees; SC as the minimum distance between the palms in both-arm circumduction, while holding the measuring stick with both elbows fully straighten; CMJ is measured as a difference between standing reach-height and one arm jump height from the standing position (using Elan/Slovenia jumping-equipment); TJ as the distance routed in a triple alternate-leg jump from the standing starting position (both legs - right leg – left leg – both legs; or vice-versa); HEX as the time (measured electronically by Brower Timing System, USA) required to perform 18 (3 x 6) double leg hops from the centre of a hexagon over each side and back to the center in a continuous clockwise sequence (drawn on the floor, the hexagon sides are 61 cm long meeting to form 120 degrees angles); and A20M is measured as the time (Brower Timing, Draper/UT/USA) needed to perform simple a 4-time-5-meters shuttle run (4x5 meters run in opposite directions).[11-14]

For the multiple-item tests (all variables with the exception of cardiovascular endurance tests) reliability indicator Cronbach-Alpha ranged from 0.79 (HEX) to 0.97 (S&R) in the motor tests, and 0.81 (abdominal skinfold) to 0.99 (BH) in the morphological tests. For the single-item variables, average correlation coefficients (average correlations between three measurements – see later text) were above 0.80, all defining acceptable to high intraobserver reliability of the tests.

Experiment: The first testing (I) was performed during the first week of the pre-competition period. The morphological variables and endurance status were measured on Monday; flexibility, explosive strength and agility tests on Tuesday, while Wednesday was a spare day (for eventual non-completed testing); all after 10-15 minutes warm up and light stretching, with no intensive training on the preceding day. The Pre-C period

Table 1. Descriptive statistics and significance of the analysis of the variance for the repeated measures in the first, second and third measurement

HIGH-LEVEL	First measurement	Second measurement	Third measurement
	X ± SD	X ± SD	X ± SD
BH (cm)	190.00 ± 6.88	191.05 ± 6.66	190.09 ± 6.31
BW (kg)	90.28 ± 4.21	91.52 ± 4.99	91.25 ± 4.22
BF% (%)	10.97 ± 2.40	10.01 ± 2.13	10.18 ± 2.34
LBM (kg)	80.42 ± 4.14	82.48 ± 4.22	81.98 ± 4.18
HS (cm)	24.71 ± 1.21	24.72 ± 1.23	24.99 ± 1.31
AS (cm)	193.34 ± 8.23	194.23 ± 8.11	192.89 ± 8.13
SR20M (level/sublevel)	8.79 ± 1.31	10.23 ± 1.39[a]	10.07 ± 1.20[a]
VO_2 (ml kg^{-1} min^{-1})	56.00 ± 3.43	59.81 ± 3.50[a]	59.31 ± 3.00[a]
S&R (cm)	13.12 ± 4.82	15.20 ± 5.44	15.39 ± 5.01
SC (cm)*	95.56 ± 18.59	93.31 ± 16.55	93.94 ± 14.93
CMJ (cm)	51.06 ± 6.67	57.51 ± 7.86[a]	56.32 ± 8.38[b]
TJ (cm)	700.71 ± 45.04	761.71 ± 41.14[a]	730.50 ± 45.58[ab]
HEX (s)*	10.80 ± 1.13	9.92 ± 1.03[a]	10.03 ± 1.03[a]
A20M (s)*	5.02 ± 0.27	4.81 ± 0.20[a]	4.99 ± 0.24

LEGEND: body height - BH, body weight - BW, calculated body fat percentage - BF%, lean body mass - LBM, hand span - HS, arm span - AS, maximal multi-level shuttle-run endurance test – SR20M, maximal relative oxygen consumption - VO_2, sit and reach - S&R, maximal shoulder circumduction – SC, countermovement jump test - CMJ, alternate leg triple jump test – TJ, hexagon test – HEX, 20 m agility test - A20M; [a] significantly different from the First; [b] significantly different from the Second; * ability improvement is observed as a numeric decrease

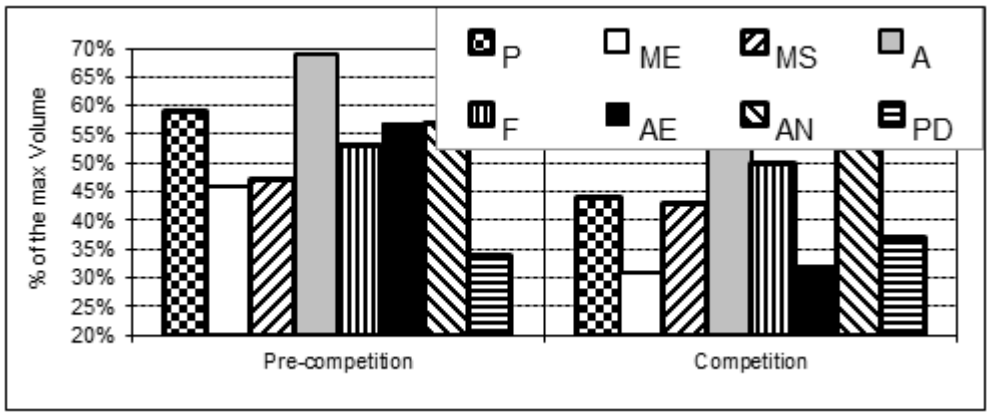

Fig. 1. - Percentage of the maximum volume of the training for each component in the pre-competition and competition period; P - power (explosive strength); ME – muscular endurance; MS – maximal strength; A - Agility; F - flexibility; AE – aerobic endurance; AN – anaerobic endurance; PD – practice drills

lasted 7 weeks, consisting of 2-4 weekly sessions for practice drills and competitive, non-official games and of 8-10 weekly sessions aimed at physical conditioning. The subjects participated in the second (II) testing from the fifth (Monday) to seventh (Wednesday) day after finishing the Pre-C period (5 – 7 days after the last serious training session, with a preceding day-off (Sunday)). The II testing was completed at the same dynamic as the I one. The competition period (between the II and III testing) lasted 14 weeks and consisted of 1-3 weekly physical conditioning sessions, 4-6 practice drills sessions and 1 – 3 official games (National Championship League, National Cup and IHF Cup at almost equal dynamics for both teams). The third testing (III) was performed a week after the final official game in the competitive half-season the same way as II testing. The

Pre-C and competition seasons' training and workouts for all the subjects were planned, programmed and instructed by one of the authors of this study.

The main scope of the investigation was the motor and endurance status, so all of the measured morphological variables (skinfolds) are not presented in the tables, but only those variables calculated on the basis of the measured ones (BF% and LBM). However, authors will be pleased to provide all details regarding non-presented data to all interested parties.

Statistical Analysis: In spite of the descriptive statistics (Mean, Standard Deviation), the differences between the I, II and III test results have been established using the repeated measurements analysis of variance (ANOVA). ANOVA was calculated between: the I and II (I-II), the II and III (II-III), and between the I and III testing results (I-III), for each group separately. The ANOVA coefficients were considered significant at a level of 5%. All the calculations were made using the *Statsoft's Statistica ver 6.*

Finally, we would like to mention that we purposely used the motor-endurance tests where the body size have a significant influence on the subjects' results, because we were of the opinion that in a sport like handball, where athletes body dimension (BH and BW mostly) is directly related to different sport-specific movement patterns (jumping, running, etc.), an assessment of any kind of muscle capability has to be performed taking into account the effect of the body's dimensions[13-14]. Also, since measurements and publication of the data are approved by the National sport authorities, and all subjects gave their informed consent, this study was not exclusively scientifically oriented, but intended to be applicable in the sport of handball also. Therefore, most of the tests used are relatively simple to perform which will allow all interested parties to test their athletes and compare the observed results here presented regardless of the available equipment.

RESULTS

In Table 1, the descriptive statistics and the significance of the differences between the first (I), second (II) and third (III) measurements are shown.

None of the six morphological measures changed significantly from I to II. Also, between II and III measurement (II-III) no significant morphological changes are observed.

The subjects improved their performance in six of eight of the motor-endurance tests during the Pre-C period, and most of PF measures remained relatively stable during the competition half-season (between the II and III measurement). More precisely, although some of the results decreased during the competitive half-season (A20M for example), the positive changes achieved during the Pre-C period (I-II) allowed for maintenance on a generally significantly higher level in the III, than in the I measurement.

DISCUSSION

Physical fitness profile of advanced male handball players

The BW and LBM values observed herein are very similar to the values previously reported in high-performance handball teams. For example, in one of the rare study dealing with the MHP of exceptional quality published so far, Gorostiaga et al. (2005) [15] presented data of one of the world's leading handball team and defined 95.2 ± 13 kg; 81.7 ± 9 kg for BW and LBM respectively. Probably, the higher variability (standard deviations) of the results from their study is a consequence of the different approach in the sampling of the subjects (explained in the Method section). Rannou et al. (2001)[7] presented values of French MHP (National and International level). When comparing those data and the here presented ones, we found similarity in BH (190 cm in French Internationals) and VO_2 (58.7 ml min $^{-1}$ kg^{-1}), but also some lower values of BF% in Croatian comparing to French MHP (12 – 13%). Our opinion is that there are two possible reasons for such difference in the BF%. First, as stated in the Introduction, handball rules changed in 2002, which undoubtedly increased dynamics of the play, and probably (although not extensively studied) determined body build of athletes. Second, it is possible that Rannou and his associates included goalkeepers in their study [7] (not specified in their text) which could increase the average values of the BF% in their sample.

Physical fitness changes during the half season period

The significant improvements in the motor and endurance status variables, during the Pre-C were mostly expected, because of the characteristic training-aim of the Pre-C season period. In this period, the training was primarily focused on an improvement of the motor and endurance status

(physical conditioning). Characteristics of this particular period are shown in Figure 1.

Handball is a high-power game. Explosive movements, sprints, repeated jumps and a direction change, requires an extreme power level, which has to be accomplished with mounting agility. Today, it is generally accepted that power and agility, like endurance performance, can be considerably improved with training. But, mainly because of the sampled athletes' level and their relatively high power-status, the changes in the power (explosive strength) and agility variables were not expected at the quantities achieved (Table 1). We share the opinion of some authors[16] that strength training especially plays a key role in agility development. Accordingly, during the Pre-C period all athletes performed 1.8 strength training workouts and 1.7 power training workouts on average every week. But, we can not be sure regarding direct and/or indirect influence of different training programs on agility improvement we are discussing. Namely, although agility (ability to change direction and start and stop quickly) represents an important motor quality for the successful performance in various sports little is known about its physiological and muscular determinants[17].

However, no significant II-III differences in the agility variables are very encouraging. It indicates that agility, power (explosive strength) and anaerobic-endurance workouts which occupied a significant part during the competition period (1.8 per week) complied with the practice drills (2.2 per week) and official games played, was quite enough stimuli to maintain the agility on a level achieved in the II measurement (after the Pre-C period). It directly relates to one of the questions we emphasized in the introduction, regarding the possible maintainability of the fitness gains attained during off-season training programmes (Pre-C period).[18] It seems that, the agility level achieved during the Pre-C period can be successfully maintained during the handball half-season competition period.

During the Pre-C period all the subjects performed 57% of the theoretic maximum volume in the aerobic endurance training, meaning that of the theoretic maximum for a single week (5 aerobic endurance workouts per week) the athletes performed (on average) 2.85 workouts aimed at improving their aerobic endurance capacities (note that 2.85 is 57% of 5, and the same logic should be followed for other training components in this text). Contrary to this, during the competition period (between the II and III measurement), they participated in on average (only) 0.66 aerobic endurance training-sessions per week. Therefore, the decrease (although not significant) in endurance capacity (VO_2) is not surprising if we pay attention to the obvious difference in the aerobic endurance training characteristics, that is, between the Pre-C and competition period (see Methods - Experiment).

However, it seems that explosive strength training may lead to specific neural adaptations, such as an increased rate of activation of the motor units, which will potentially affect the muscle power and movement (e.g. running, swimming, etc.) economy. Paavolainen et al. (1999)[19] in their paper, when proved the significant influence of explosive strength training on the 5-km running in endurance trained athletes, presented a model of determinants of distance running performance. Model includes three segments potentially involved in endurance performance: (1) aerobic power, (2) anaerobic power, and (3) neuromuscular capacity (including neural control, muscle forces and running mechanics). (1) Aerobic power can be almost exclusively developed through endurance training; (2) anaerobic power equally through (a) endurance training, and (b) strength and sprint training; while (3) neuromuscular capacity is practically completely related and can be develop throughout sprint and strength training. To conclude regarding our results - it is possible that not only aerobic and anaerobic endurance training, but also explosive strength training initiated significant improvements in the endurance capacities in the MHP we studied here. It mainly relates to the competition period, where aerobic endurance training took a minor part of the complete training volume, but no significant decrease in the aerobic endurance was observed. Of course, the authors are aware that these conclusions are partially speculative, and therefore have to be precisely investigated in some future studies.

We are of the opinion that the changes in flexibility are not adequate and satisfactory (no significant differences in any of the studied flexibility variables in both groups). Knowing the high trainability, a significant improvement in flexibility was expected. For example, Zakas et al. (2003)[20] published a study where presented the effects of stretching during warming-up on the flexibility in junior handball athletes. They studied the improve-

ment in flexibility as a result of the warm up and stretching exercise in junior handball players, and found significant improvements in flexibility and concluded that it improves as a result of muscle elongation during warming-up or even through an incorporated pathetic stretching program. Therefore, from a professional point of view, the results of our study can not satisfy us. The subjects in our experiment participated on average 5% of each training session (5-10 minutes) in flexibility training (proprioceptive stretching, passive and active stretching, and relaxation techniques), with no difference in volume of the flexibility training between the Pre-C and competition period (see Methods). It seems that although regularly performed flexibility training was not adequate in volume (5-10 minute of each training session, while Zakas and his associates in the previously cited article [20] reported significant improvements in flexibility with 20 min workouts). An additional possibility is that the athletes in our experiment did not execute the flexibility workouts properly. In particular, most of the characteristic stretching workouts and exercises are self – controlled by the athlete himself. In other words, there are no quantitative parameters in the evaluation of the intensity of flexibility training (e.g. a lifted weight in strength training, and/or heart-rate during the cardiovascular endurance training, etc). Consequently, coaches are not able to supervise a flexibility workout as they can supervise some other conditioning program (for example - strength and/or endurance training). As a conclusion, the authors are of the opinion that in future training programs, higher standards in flexibility training have to be designed, by means of (a) increasing the total volume of the flexibility training, and (b) assuring a certain control of the training standards and quality.

It is interesting that the morphological changes are not as significant as the motor-endurance changes (see Results). The authors are of the opinion that the main reason for the above stated can be found in the initial morphological status of the subjects (highly trained – athletic physique). Certain support to our conclusion can be found in some recent studies performed on high level athletes from different sports. Most of the studies performed on the well-trained athletes showed similar trends for most of the morphological variables in different season-periods. [21-23] As a brief review, Casajus (2001)[21] found no significant seasonal 5-month variation (from September to February) in BW, although observed a statistically significant decrease in BF% and the sum of six skinfolds (note that we found significant decrease in the BF% for the TOP-LEVEL group); while Gabett (2005) [22] presented comparable results when studied rugby players during the competitive season. Finally, Schmidt et al. (2005) [23] showed no significant changes in BW, BF%, and LBM from pre- (late October) to mid- (late January) to postseason (late March) in college wrestlers, not surprising knowing that wrestlers are like other martial art athletes very concerned about their weight limit and consequently BF%. Accordingly, we can support the considerations that substantial morphological changes are usually unexpected in mature, adult, previously well-trained athletes.

CONCLUSION

Based on the results presented and discussed herein, the following conclusions can be drawn.

It seems that the agility level achieved during the Pre-C period can be successfully maintained during the handball half-season competition period. But, since agility slightly decreased during the competition half-season period, it is reasonable to suggest that in the following preparation period (2nd half-season Pre-C period) coaches should try to improve agility (again), because of the second competitive half-season.

Handball athletes of a high level must attend 1-2 aerobic exercise sessions weekly, if aerobic endurance status is being aimed at as a training goal.

Since improvements in flexibility during the half season period were relatively low we can suggest certain control of the flexibility training standards and quality (for example: permanent and not only periodical testing, using exercises where a confident definition of the training intensity can be realized, etc.).

Finally, we are of the opinion that an improvement in the PF can be achieved almost exclusively during the Pre-C periods. In this manner, understanding and foreseeing the changes-dynamics during the half-season period is probably one of the most important factors in handball, but also in other league sports (like basketball, football, etc.).

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ПОЛУСЕЗОНСКИ ПРОМЕНИ НА ФИЗИЧКАТА ПОДГОТВЕНОСТ КАЈ ВРВНИТЕ РАКОМЕТАРИ

УДК:796.322.015.132
(Оригинален научен труд)

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Абстракт

Цел на трудот беше да се утврдат индивидуалните промени во мерките за проценување на нивото на фитнесот кај врвните ракометари од машки пол. Во приерокот влегоа 32 ракометари кои играат во прва лига. Следена е состојбата на шест мофолошки, две варијабли за проценување на кардиоваскуларната издржливост и шест моторни варијабли. Испитаниицте се анализирани на почетокот на подготвителниот период (I),на крајот на подготвителниот период (II) и на крајот на полусезоната. За да се утврдат промените меѓу мерењата применета е униваријантна анализа на варијансата (АНОВА). Меѓу првото и второто мерење АНОВАТА покажа значајни промени во кардиоваскуларната издржливост, агилноста и експлозивната силина, додека во повеќето мерки не настанале статистички значајни промени меѓу II и III мерење. Подготвителниот период довел до значајни промени во повеќето моторни тестови, без разлика на високото ниво на натпреварувачкиот квалитет на спортистите. Истовремено не настанале значајни промени во мерките за проценување на морфолошкиот статус, со што се потврдува хипотезата дека тешко можат да настнат морфолошки промени кај добро тренирани спортисти.

Клучни зборови: *екипен спорт, моторичко-функционален статус, специфични тестови, физичка подготвеност*