Effects of Two Different Training Periodization Models on Physical and Physiological Aspects of Elite Female Team Handball Players

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Abstract

Manchado, C, Cortell-Tormo, JM, and Tortosa-Martínez, J. Effects of two different training periodization models on physical and physiological aspects of elite female team handball players. *J Strength Cond Res* 32(1): 280–287, 2018—The aim of this study was to compare training-induced changes in selected physiological and physical team handball performance factors after 2 training periodization models: traditional periodization (TP) vs. block periodization (BP). Eleven female team handball players who played over 2 consecutive seasons for a Spanish first league team were assessed twice per season during a training cycle. On each occasion, participants completed anthropometric, maximal strength, and lower-body power assessments. In addition, incremental tests to determine maximum oxygen uptake ($\dot{V}O_2max$), sprint- and sport-specific throwing velocity tests were performed. Block periodization group experienced significantly greater improvements than TP on squat jump (5.97%; $p < 0.001$), countermovement jump (8.76%; $p = 0.011$), hand-grip strength (8.22%; $p = 0.029$), bench press 1 repetition maximum (1RM) (5.14%; $p = 0.049$), 10-m sprint (−6.19%; $p < 0.001$), and 20-m sprint (2.95%; $p = 0.008$). Greater changes in BP group ($p \leq 0.05$) were also found for the throwing velocities in sport-specific tests compared with the TP group. No significant difference between the groups were detected for the half-squat 1RM ($p = 0.15$) and the $\dot{V}O_2max$ ($p = 0.44$). These findings suggest that BP may be more effective than TP for improving important physiological and physical team handball performance factors in high level female handball players.

Key Words traditional periodization, block periodization, strength, throwing velocity, team sports

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Introduction

Training periodization is a strategy to promote long-term training and performance improvements with preplanned systematic variations in training specificity, intensity, and volume organized in periods or cycles within an overall program. The contemporary theory of training was established in the 1960s and early 1970s by Matveyev (24) and Ozolin (25) and became known as the classic or traditional periodization (TP) training model. In this model, training starts with high-volume and low-intensity workloads and shifts to an increase in the intensity and a decrease in the volume as the athlete progresses toward the competition phase (24). The periodization model at that time was largely based on individual sports and did not consider team sports scheduling. For example, modern team sports require achieving multipeak performances during a season, which the TP model may not provide. Team sports also require a high level of performance in many abilities simultaneously. In a TP model, some noncompatible capacities (e.g., strength and aerobic endurance) trained at the same time may interfere with specific biological adaptations (32,34). The combination of these different adaptation responses may cause excessive fatigue accumulation and increase the risk of overtraining. Furthermore, mixed training may also have as a consequence that the stimuli for each individual capacity may be insufficient for achieving further improvements (16).

To overcome the limitations of TP, a new training model was developed (16), called block periodization (BP). In BP, the different abilities needed for peak performance are trained consecutively in specialized mesocycle blocks. Concentrated workloads may produce sufficient stimuli for improving specific abilities in highly trained athletes. Consequently, the risk of exceeding the limit of homeostatic regulation is reduced because it may happen with concurrent training, where the stress response may become prevalent, causing a serious decline in performance (16).

Empirical information comparing training periodization models is very limited, and most of the research studies to date has been conducted in individual endurance sports focusing either on endurance variables (1,2,7,17,29) or in strength/power (26), or in team sports but considering only strength training programs (15). In individual sports, García-Pallarés et al. (7), in their study with 10 male elite world class kayakers, concluded that a BP program produced significantly better results than a TP program when it came to improving kayak peak performance (gain of 6.2 vs. 3.4%; $p \leq 0.05$) and kayak peak power (gain 14.2 vs. 6.0%; $p \leq 0.05$). A second study was conducted to investigate the effects of BP on 21 alpine skiers (2), where the authors suggested that BP could be a good way to efficiently improve maximum oxygen uptake ($\dot{V}O_2max$) with significant increases by 6% ($p < 0.01$), in peak power output by 5.5% ($p < 0.01$), as well as power output and ventilator threshold by 9.6% ($p < 0.01$). Issurin et al. (17), in a study conducted with 23 male elite canoeists, concluded that a BP program was more efficient for improving on-water power output, propulsive efficiency, and power on stroke simulated ergometer. Ronnestad et al. (29) concluded that BP provided superior adaptations compared to TP for trained cyclists. Last, a study with 19 subelite cross country and biathlon athletes (1) concluded that athletes obtained significant increases in $\dot{V}O_2max$ test scores by 2.6% ($p < 0.5$) and work time to exhaustion by 6.1% ($p < 0.5$) after a BP training model, whereas the control group did not show any significant changes after a TP training model. Concerning strength training, Painter et al. (26) reported greater improvements on strength and power in track and field athletes when a BP was used compared with a daily undulating periodized program.

In regards to team sports, only a few studies have compared the effects of different training periodization models and they focused only in strength training, which gives an incomplete picture of the possible consequences of concurrent training in team sports. Concerning resistance training, Hoffman et al. (15) compared 3 different periodization models (nonperiodized, traditional periodized linear, and planned nonlinear) in 51 experienced American Football players and did not report any significant differences in strength performance between the groups. Focusing in women's sport, none of the studies are related to performance factors for a specific sport (3,4,18). For example, Bartolomei et al. (3) reported better results in recreationally strength-trained women after a weekly undulating periodized training (which is similar to a TP model) compared with BP training for increasing maximal strength and muscle size in the lower body.

Thus, despite its widespread use in coaching practices and the extensive lay literature that is available on these periodization models, to the best of our knowledge, there are no published scientific studies exploring their effectiveness when applied to team sports, such as handball. The major determinants for handball performance include anthropometric characteristics (11,20,31,33), aerobic capacity (12,19,27), as well as maximal and explosive strength (5,8,11,14,22). Considering that there is a need to devote long periods of time to technical and tactical training, not much time remains left for an effective periodization of physical factors.

Thus, the aim of this study was to compare the effects of these 2 different training periodization models (i.e., TP vs. BP) on important physical and physiological handball performance factors measured by these different tests. It was hypothesized that a BP approach could be more effective than TP for improving female handball players' physiological and physical performance factors.

Methods

Experimental Approach to the Problem

A cross-over design was used in this study. During the first training cycle (17 weeks from August to the end of November) over 2 consecutive seasons, training was conducted after the 2 periodization models. In season 1 (S1), players underwent a training program based on the TP model, whereas a BP model was used in season 2 (S2). In both seasons (S1 and S2), the training cycle finished at the end of November because 5 players had to play in December for their national team, either at the World Championship or at the European Championship.

Table 1 shows a summary of the training periodization structures used in this study. Training cycles were divided into 3 phases (17 weeks): general preparation (GP), specific preparation (SP), and competition (C) for the TP, and accumulation (A), transformation (T), and realization (R) for the BP. Physical tests were conducted before (preintervention) and after (postintervention) the 17-week intervention period. The main training targets for each phase are also indicated in Table 1.

Subjects

All senior female handball players who played for a Spanish first division team were initially selected ($n = 14$) for a follow-up over 2 consecutive seasons. Three players left the team after the first season. Thus, 11 players, those who played over 2 consecutive seasons, took part in this study. All participants were part of the same team, training an average of 16 $h \cdot wk^{-1}$. Mean characteristics of participants were as follows: (Mean +/− SD) age 18–27 years, height 168.8 ± 7.2 cm, and body mass 64.4 ± 5.3 at the beginning of the study. Players had at least 2 years of familiarization with testing procedures used in this investigation and at least 4 years of experience in resistance training. All players received verbal and written information about the benefits and risks of the investigation and provided informed written consent to participate in all procedures, which was signed by a parent or legal guardian in the case of those who had not reached the legal adult age in Spanish law (18 years). The study was performed according to the ethical standards established by the Helsinki Declaration of 1975 and was approved by the Ethics Committee of Alicante University.

Table 1. Study design.*†

Week Season 1	August–November 1–4 TP model	5–8	9–16	Last week November 17 Season 1	Season 2	August–November 1–5 BP model	6–10	11–16	Last week November 17 Season 2
(T_{TP0})	GP	SP	C	(T_{TP1})	(T_{BP0})	A	T	R	(T_{BP1})
	LIT GS BT	MIT MP TeP TTS MS	TTS SSE SSSP			HIT MSt TeP	SSE TTS MP	TTS MS SSSP	

*TP = traditional periodization; BP = block periodization; T_{TP0} = preintervention test TP season; GP = general preparation; SP = specific preparation; C = competition; T_{TP1} = postintervention test TP season; T_{BP0} = preintervention test BP season; A = accumulation; T = transformation; R = realization; T_{BP1} = postintervention test BP season; LIT = low-intensity endurance training; MIT = medium-intensity endurance training; TTS = techno-tactical skills; HIT = high-intensity endurance training; SSE = sport-specific endurance; GS = general strength; MP = maximal power; MSt = maximal strength; MS = maximal speed; BT = basic technique; TeP = technique perfection; SSSP = sport-specific strength and power.
†Summary of training plan, main training targets, and testing calendar for both cycles.

Procedures

Training. The main differences between the 2 training periodization models (TP and BP) involved the different endurance and strength training programs performed by the players in each model.

Endurance. During the GP of the TP (S1) and the accumulation period of the BP (S2), the main objective was to develop aerobic capacity and aerobic power. Three weekly training sessions were performed: 40 minutes of traditional low-intensity training at 70% of their maximal heart rate (HRmax) for TP, and 30 minutes of high-intensity aerobic training for BP. The high-intensity aerobic sessions, followed the Helgerud et al. (13) methodology, consisting of continuous intervals of 4-minute hard workout, and 3-minute easy workout, repeating this pattern 4 times. The hard workout consisted of running at 90–95% HRmax, and the easy workout at 70% HRmax. The total time spent on endurance training during the general period of the TP (S1) and the accumulation period of the BP (S2) was similar (480/450 minutes). In the SP for TP (S1), the endurance program increased the training intensity and decreased the training volume. Two weekly medium-intensity training sessions of 25 minutes at 85% HRmax were conducted. During BP (S2), specific endurance training simulating match play was conducted in the transformation period. In these sessions, technical and tactical abilities were trained in state of fatigue. Mean heart rate was 166.1 ± 3.3 $b \cdot min^{-1}$, corresponding to 84.9 ± 5.5% of HRmax. The total time spent on endurance training during the 2 periods (specific for TP and transformation for BP) was the same (200 minutes).

Strength. During the GP period in S1 and the accumulation period in S2, all participants exercised 2 $d \cdot wk^{-1}$, and the exercises performed were the same for each season. The difference between the 2 periods was only the intensity (% of RM) and volume (number of repetitions × sets) used. The training program included upper-body and lower-body strength exercises (bench press, half squat, leg press, leg extension, lying leg curl, cable pull-down, cable pushdown, and curl biceps). The training was individualized for each participant based on their one repetition maximum (1RM). During the first mesocycle of S1, the program consisted of a 4-week mesocycle with decreasing training volume and increasing intensity (3 × 10 rep at 60% of 1RM, 3 × 10 rep at 65% of 1RM, 3 × 9 rep at 70% of 1RM, and 3 × 8 rep at 75% of 1RM), and in S2 the program also consisted of a 4-week mesocycle focusing on maximal strength, with high loads (80–95% of 1RM) and low number of repetitions (1–4 RM). During the second mesocycle, all participants exercised 2 days per week. The SP in S1 consisted of a 4-week mesocycle focusing on power (3 weeks 5–6 rep at 75–85% of 1RM and the last week at 50–60% of 1RM). During the transformation mesocycle in S2, the training focus shifted from maximal strength to maximal power. Participants used workloads ranging from 75–80% of 1RM, performing each repetition at a maximal intended concentric velocity and with a complete recovery between sets (3 minutes). The last mesocycle for both periodization models was focused on sport-specific strength and power training consisting in a circuit (3 sets of 8 exercises) conducted in pairs with alternative maximal intervention during 32 seconds (2 times 8 seconds each of the players), 1-minute recovery between exercises, and 3 minutes between sets.

Testing. At the beginning and ending of the 2 periods, different tests were conducted to measure physiological and physical handball performance variables. The test protocol was conducted in 2 different sessions. Session 1: Anthropometry, vertical jump, 20-m sprint, maximal isometric hand-grip force, and dynamic strength (1RM) tests. Session 2: Throwing velocity and $\dot{V}O_2max$ tests.

Anthropometry. Height and weight measurements were made on a set of scales (Seca, Barcelona, Spain) with an accuracy of 0.01 kg and 0.001 m, respectively. The body mass index (BMI) was calculated as weight (kilogram) divided by height (m^2).

Throwing Velocity Test. Ballistic strength production during a handball overarm throw was evaluated. Throwing velocity was assessed using a radar gun (Stalker Pro, Inc., Plano, TX, USA), with a 100-Hz sampling frequency and with 0.045 $m \cdot s^{-1}$ sensitivity, placed behind the goalpost and in a perpendicular direction to the player. The same procedure adopted in this study has been previously used by García-Esposito et al. (6) and by Vila et al. (33) to assess handball players. Before the throwing velocity test, participants performed a 15-minute warm-up focusing on overhead throwing. The participants performed 2 different protocols of throw, 1 with a goalkeeper and 1 without. For both protocols, participants threw a standard handball ball as fast as possible toward a standard goal, using a single hand and their personal technique. The sequence of throwing was: a standing shot from just behind the 7-m penalty mark (S7), a standing shot from just behind the 9-m line (S9), 3-step run-up shot from 9 m (3S9), and a 3-step run-up jump shot from 9 m (3SJ9). Three shots of each type were performed and the best trial was used for further analysis. Only shots sent to the goalpost were used for analysis. For motivational purposes, players were immediately informed of their performance. A 3-minute rest elapsed between shots to avoid fatigue (6). The intraclass correlation coefficients (ICCs) for the S7 with and without goalkeeper were 0.93 and 0.92, respectively, whereas the *SEM*s were 1.85 and 2.09, respectively. The ICCs for the S9 with and without goalkeeper were 0.91 and 0.89, respectively, whereas the *SEM*s were 2.16 and 2.42, respectively. For the 3S9 with and without goalkeeper, the ICCs were 0.86 and 0.88, respectively, whereas the *SEM*s were 2.05 and 2.07, respectively. Finally, the ICCs for the 3SJ9 with and without goalkeeper were 0.83 and 0.86, respectively, whereas the *SEM*s were 1.57 and 1.53, respectively.

Maximal Isometric Hand-Grip Force Test. The grip strength of the dominant hand was measured using a standard adjustable digital hand-grip dynamometer (T.K.K. 5401; Takei Equipment Industrial, Tokyo, Japan) with a sensitivity of 10 N. Both the anthropometric equipment and the hand-grip dynamometer were calibrated before each assessment. All participants were tested after 3 minutes of independent warm-up. The test was conducted with the extended arm parallel to the body. Movements of the arm or wrist were not allowed. Peak developed strength was recorded. The players performed 2 repetitions at maximum intensity with a 3-minute rest between trials to minimize the effects of fatigue. The best trial was used for further analysis (33). The ICC for this test was 0.90 and the *SEM* was 1.32.

Vertical Jump Test. Each participant performed 2 kinds of vertical jumps, the squat jump (SJ) and the countermovement jump (CMJ), on a jump mat (Ergo Jump Bosco System; Byomedic, SCP, Barcelona, Spain). The jump height was determined from the flight time using standard calculation methods. To avoid unmeasurable work, horizontal and lateral displacements were minimized, and the hands were kept on the hips throughout the tests (33). Participants completed 3 attempts of each type of jump with a 3-minute rest between trials to avoid fatigue. The best one was used for the subsequent statistical analysis. The ICC for the SJ was 0.85 and the *SEM* was 1.52. In regards to the CMJ, the ICC was 0.89 and the *SEM* 1.42.

Maximal Dynamic Strength. One repetition maximum was determined as the highest weight that could be lifted through the full range of motion with correct technique. For the lower body, participants performed the half squat from a fully extended position starting with shoulders in contact with the bar. On command, the participants performed a controlled eccentric squat to a knee angle of 90°, followed by a concentric leg extension (as fast as possible) returning to full extension, without pausing. For the upper body, athletes performed the bench press lowering the bar from a fully extended arm position until the bar was at chest height but not touching and then immediately extended the arms as fast as possible to return to the starting position (28).

Maximum Oxygen Uptake ($\dot{V}O_2max$). $\dot{V}O_2max$ and HRmax were determined during an incremental maximal intensity test on a calibrated treadmill. The following test protocol was used: the initial velocity was set at 2.4 $m \cdot s^{-1}$ and increased to 2.8 $m \cdot s^{-1}$ after 5 minutes, and the inclination of the treadmill was 1%. After this warm-up of 10 minutes, inclination was increased to 2%, and velocity was increased by 0.2 $m \cdot s^{-1}$ every 30 seconds until exhaustion. Each player was instructed and verbally encouraged to give a maximal effort. Duration of the tests varied between 4 and 7 minutes depending on individual aerobic performance. Throughout the test, gas exchange was measured breath by breath using a ZAN spirometric system (ZAN Messgeräte, Oberthulba, Germany). The analyzer was calibrated daily using a 1-L calibrated syringe and a gas mixture of known concentration (5% CO_2, 16% O_2, and 79% N_2). $\dot{V}O_2max$ was determined as the highest mean value of 15 consecutive seconds. Heart rate was measured continuously using a heart rate monitor (Team System; Polar Electro Oy, Kempele, Finland). HRmax was determined as the highest value that was obtained when the subject was exhausted.

Sprint Performance. Participants performed two 20-m maximal sprints starting in a stationary position and the fastest time was recorded. The sprint was performed on the handball court and was recorded by photocells (Racetime2 Light radio; Microgate, Bolzano, Italy) placed at the start, at 10 m and at the finish lines. The ICC for this test was 0.84 and the *SEM* was 0.06.

Statistical Analyses

Statistical analysis was performed using the SPSS statistical package version (SPSS 21.0 for Windows). Descriptive baseline characteristics were tabulated as mean values and *SD*s (Table 2). Data distribution was checked by the Shapiro-Wilk test, and homoscedasticity was checked by the Levene test. Baseline group differences analysis between the 2 seasons was conducted using unpaired T-test for normally distributed variables and the Mann-Whitney *U*-test for non-normally distributed variables. To analyze and compare the changes in the different physiological and physical handball performance factors over the 2 training periodization methods, univariate analysis of variance of repeated measures were performed. Box's M test was applied to test the homogeneity of variance–covariance matrices. Effect size was calculated using partial eta squared. Changes in both training models (TP and BP) individually, between T0 and T1 time points, were estimated as the difference between the mean values and the percentage of change (%). All reported p values are 2 sided and the significance level was set at 0.05.

Results

No significant differences were observed at baseline for any of the measured variables except for the throwing velocity expressed in the 3SJ9 shot ($p = 0.044$).

A comparison between changes in body composition and fitness variables, after TP and BP, is shown in Table 2. No significant group (TP vs. BP) × time (pre vs. post) interactions or main effect of group or time were found in either body mass or BMI.

Fitness Characteristics

Significant group × time interactions were found for SJ ($F = 37.88$, $p = 0.000$, ES = 0.79); CMJ ($F = 9.60$, $p = 0.011$, ES = 0.49); IHG ($F = 6.52$, $p = 0.029$, ES = 0.39); 10-m sprint ($F = 28.30$, $p = 0.000$, ES = 0.74), 20-m sprint ($F = 11.12$, $p = 0.008$, ES = 0.53), and bench press ($F = 4.55$, $p = 0.049$, ES = 0.31). Improvements were greater in the BP group compared with the TP group of 5.97, 8.76, 8.22, 6.19, 2.95, and 5.14% for SJ, CMJ, IHG, 10-m sprint, 20-m sprint, and bench press 1RM, respectively. No significant group × time interactions were found for the half-squat 1RM ($F = 2.43$, $p = 0.15$, ES = 0.19) and $\dot{V}O_2max$ ($F = 0.63$, $p = 0.44$, ES = 0.06). Significant time effects were detected for SJ ($F = 25.05$, $p = 0.001$, ES = 0.71), CMJ ($F = 12.26$, $p = 0.006$, ES = 0.55), 10-m sprint ($F = 17.62$, $p = 0.002$, ES = 0.63), 20-m sprint ($F = 56.87$, $p = 0.000$, ES = 0.85), bench press 1RM ($F = 31.27$, $p = 0.000$, ES = 0.75) and half-squat 1RM ($F = 47.22$, $p = 0.000$, ES = 0.82). No significant time effects were found for IHG ($F = 0.01$, $p = 0.93$, ES = 0.00) and $\dot{V}O_2max$ ($F = 3.94$, $p = 0.075$, ES = 0.28).

Throwing Velocity

A comparison between changes in throwing velocity, after TP and BP, is shown in Table 3. Significant group × time interactions were found for S9 with and without goalkeeper

Table 2. Changes in body composition and fitness characteristics during the 2 training cycles.*

Variables	TP				BP			
	T_{TP0}	T_{TP1}	Mean difference (CI 95%)	p	T_{BP0}	T_{BP1}	Mean difference (CI 95%)	p
Body composition								
Body mass (kg)	64.1 ± 5.2	64.5 ± 5.0	0.4 (−1.22 to 0.40)	0.289	63.8 ± 5.6	64.0 ± 5.0	0.2 (−1.10 to 0.74)	0.724
BMI ($kg \cdot m^{-2}$)	22.6 ± 1.6	22.5 ± 1.8	0.1 (−0.63 to 0.72)	0.889	22.4 ± 1.3	22.5 ± 1.4	0.1 (−0.44 to 0.22)	0.466
Fitness characteristics								
SJ (cm)	22.9 ± 3.5	23.6 ± 4.0	0.70 (0.22 to 1.16)	0.008	24.4 ± 4.2	26.6 ± 4.0	2.20 (1.32 to 3.07)	0.000
CMJ (cm)	25.8 ± 3.9	26.1 ± 3.9	0.3 (−1.38 to 1.96)	0.706	26.6 ± 4.9	29.2 ± 4.3	2.62 (2.04 to 3.20)	0.000
IHG (N)	38.6 ± 3.8	36.9 ± 4.6	−1.7 (−5.06 to 1.79)	0.31	36.6 ± 4.5	38.0 ± 4.3	1.40 (−0.35 to 3.26)	0.011
$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	44.9 ± 5.3	46.9 ± 6.0	2.0 (0.73 to 3.22)	0.005	45.8 ± 4.5	48.1 ± 4.6	2.24 (0.80 to 3.89)	0.006
10-m sprint (s)	1.88 ± 0.1	1.89 ± 0.1	0.01 (0.05 to −0.02)	0.463	1.94 ± 0.1	1.83 ± 0.1	−0.11 (−0.07 to −0.14)	0.000
20-m sprint (s)	3.33 ± 0.2	3.28 ± 0.1	−0.05 (−0.01 to −0.07)	0.007	3.37 ± 0.2	3.22 ± 0.2	−0.15 (−0.09 to −0.19)	0.000
Half squat (kg)	118.0 ± 27.9	137.5 ± 34.4	19.5 (4.05 to 34.85)	0.018	120.9 ± 25.1	151.4 ± 31.2	30.5 (26.18 to 34.81)	0.000
Bench press (kg)	39.3 ± 8.3	43.6 ± 7.8	4.3 (2.43 to 6.07)	0.000	34.5 ± 8.1	40.1 ± 8.3	11.06 (4.69 to 17.43)	0.003

*TP = traditional periodization; BP = block periodization; T_{TP0} = preintervention test TP season; T_{TP1} = postintervention test TP season; CI = confidence interval; T_{BP0} = preintervention test BP season; T_{BP1} = postintervention test BP season; BMI = body mass index; SJ = squat jump; CMJ = countermovement jump; IHG = isometric hand-grip force.

Table 3. Changes in throwing velocity during the two training cycles.*

Variables	TP				BP			
	T_{TP0}	T_{TP1}	Mean difference (CI 95%)	p	T_{BP0}	T_{BP1}	Mean difference (CI 95%)	p
7 m	68.4 ± 7.6	68.5 ± 7.9	0.1 (−2.76 to 2.91)	0.954	63.3 ± 8.2	66.0 ± 9.1	2.68 (0.86 to 4.50)	0.009
7 m + GK	68.9 ± 6.8	70.7 ± 6.6	1.80 (0.57 to 3.12)	0.103	64.7 ± 7.6	66.6 ± 8.9	1.89 (−0.02 to 3.81)	0.050
9 m	69.1 ± 7.6	68.6 ± 7.2	−0.50 (−3.19 to 2.31)	0.723	62.7 ± 8.6	68.0 ± 8.8	5.30 (2.95 to 7.63)	0.001
9 m + GK	70.3 ± 6.6	69.2 ± 7.3	−1.12 (−4.73 to 2.48)	0.500	63.6 ± 8.4	68.1 ± 9.3	4.51 (2.45 to 6.57)	0.001
9 m, 3 steps	71.9 ± 7.3	70.80 ± 6.7	−1.10 (−4.52 to 2.35)	0.487	66.4 ± 7.5	69.8 ± 8.2	3.36 (2.10 to 4.64)	0.000
9 m, 3 steps + GK	72.3 ± 4.4	71.4 ± 4.6	−0.90 (−4.22 to 2.37)	0.542	67.6 ± 7.2	71.4 ± 8.0	3.80 (2.50 to 5.10)	0.000
9 m, jump	69.1 ± 3.7	67.7 ± 3.6	−1.40 (−3.62 to 0.82)	0.187	65.2 ± 4.3	67.9 ± 5.5	2.70 (1.12 to 4.29)	0.004
9 m, jump + GK	68.6 ± 4.2	69.1 ± 4.0	0.50 (−2.30 to 3.30)	0.696	66.0 ± 3.7	69.4 ± 4.0	3.41 (1.65 to 5.17)	0.002

*TP = traditional periodization; BP = block periodization; T_{TP0} = preintervention test TP season; T_{TP1} = postintervention test TP season; CI = confidence interval; T_{BP0} = preintervention test BP season; T_{BP1} = postintervention test BP season; GK = goalkeeper.

($F = 7.02$, $p = 0.026$, ES = 0.44 and $F = 7.71$, $p = 0.022$, ES = 0.46, respectively), 3S9 with and without goalkeeper ($F = 11.43$, $p = 0.008$, ES = 0.56 and $F = 6.29$, $p = 0.036$, ES = 0.44, respectively), and 3SJ9 with and without goalkeeper ($F = 5.58$, $p = 0.042$, ES = 0.38 and $F = 8.27$, $p = 0.018$, ES = 0.48, respectively). Improvements were greater in the BP group compared with the TP group of 8.23, 8.41, 6.86, 6.59, 5.88, and 6.17% for S9 with and without goalkeeper, 3S9 with and without goalkeeper, and 3SJ9 with and without goalkeeper, respectively. No significant group × time interactions were found for the S7 with and without goalkeeper ($F = 0.003$, $p = 0.95$, ES = 0.00 and $F = 2.71$, $p = 0.134$, ES = 0.23, respectively). Significant time effects were detected for S7 with goalkeeper ($F = 10.19$, $p = 0.011$, ES = 0.53), S9 with and without goalkeeper ($F = 5.15$, $p = 0.049$, ES = 0.36 and $F = 28.08$, $p = 0.000$, ES = 0.76, respectively), and 3SJ9 with goalkeeper ($F = 5.51$, $p = 0.043$, ES = 0.38). No significant time effects were found for S7 without goalkeeper ($F = 3.92$, $p = 0.079$, ES = 0.30), 3S9 with and without goalkeeper ($F = 2.73$, $p = 0.129$, ES = 0.23 and $F = 2.79$, $p = 0.137$, ES = 0.25, respectively), and 3SJ9 without goalkeeper ($F = 1.96$, $p = 0.195$, ES = 0.18).

Discussion

In this study, the magnitude of improvements in the fitness characteristics in 2 different seasons, using TP or BP, was compared. In both periodization models, improvements occurred in the different variables under study, with the exception of the throwing velocity in the TP. The main finding of this study was that a block periodized training showed to be more effective than traditional periodized training for improving physiological and physical handball key performance factors.

The few studies available in the literature comparing different periodization models have also shown better training results using the BP model when compared with other types of periodization models (1,2,7,17,29). Consistently with this study, Painter et al. (26) concluded that BP was more efficient than a daily undulated model in producing strength gains based on calculated training efficiency scores.

When analyzing experimental studies comparing different periodization models on female participants, Bartolomei et al. (3) reported better results in recreationally trained women for increasing maximal strength and muscle size in the lower body after a weekly undulating periodized training compared with BP training. Thus, BP training seems to be more effective for athletes with advanced training status, with probably higher percentage of lean mass, whereas weekly undulating periodized training seems to be more effective for those who are recreationally trained, but more research is needed to confirm this claim.

To the best of our knowledge, this is the first study to compare these 2 different periodization training approaches in team sports such as handball. Handball is a high-intensity intermittent sport that requires a complex combination of strength and endurance training in parallel to the necessary training on the technical and tactical aspects of the game (12,27). Several studies have identified the physical prevailing requirements of handball in the explosive force in the upper and lower limbs (player's movement velocity, jump capacity, and throwing velocity of the ball) (5), the maximal force and muscular power (required in contact moves against the opponents) (8,11), and the aerobic capacity to maintain a high level of performance throughout the 60-minute play time (19,21,23,27).

Vertical jumping ability is an essential component in handball (23), and it is frequent in both defensive (e.g., blocking and stealing) and offensive (e.g., passing and shooting) handball actions. This study showed greater improvements in vertical jumps for BP compared with TP. Maximal dynamic strength expressed by 1RM (half squat and bench press) increased after both training programs, but greater improvements were observed for BP compared with TP. The magnitude of increases was slightly different for the upper body and the lower body, with greater improvements shown for the lower body in both training models. These findings are different from those of Gorostiaga et al. (10) who reported greater improvements ($p \leq 0.05$) for upper-extremity muscles (23%) than for lower-extremity muscles (12.2%) after 6 weeks of heavy resistance training in adolescent handball players. This difference in strength gains between upper- and lower-extremity muscles was explained in this study by a difference in initial conditioning level between knee extensor and upper body muscles. However, the characteristics of the samples in the 2 studies are quite different, making comparisons difficult.

A highly developed aerobic capacity seems to be important to reduce cardiocirculatory demands and to optimize performance during handball matches (19,21,23,27). In our study, no significant differences were found in $\dot{V}O_2max$, although on average, the improvements seemed to be slightly greater for BP (4.9%) compared with TP (2%).

Sprinting, acceleration, and rapid changes in direction are inherent to both practice and competition in handball (27). Results of this study indicated that players achieved greater improvements in acceleration capacity after the BP compared with the TP program. Concentric force development seems to be critical to sprint start performance and accordingly maximal concentric jump power seems to be related to sprint acceleration (30). Therefore, it seems logical that maximum leg strength improvements relate to improvements in the ability to jump and in acceleration capacity. In all these performance variables, the BP training cycle seemed to be more effective than TP.

Throwing ability is one of the most vital skills in handball and a very important aspect for success (11). Factors believed to influence the throwing velocity include upper- and lower-body strength and trunk strength, throwing technique, and vertical jumping ability (5). Although at baseline of S1 and S2, significant differences were observed only for the 3-step running 9-m throw with a jump, on average, S1 values were higher than S2 values. The possible explanation for this fact is that during the season before the start of the study, the team studied finished the competitive period at the end of April. During the months of May and June, players performed a specific heavy strength training work (>80% 1RM). This fact that has probably determined higher levels of strength at the beginning of S1 correlated also with a better throwing velocity level as previously explained in different studies (9,31). The results of our research showed that significant increases in throwing velocity values were detected after BP, whereas no significant increases were detected after the TP model. The strength training regimen proposed by TP may not provide sufficient stimulus for all muscle groups related to throwing velocity.

In summary, although both methods (TP and BP) produced performance improvements, BP showed greater enhancements in variables considered to be key performance factors in handball, such as explosive strength and throwing velocity (11,33). Thus, in the case of the handball team used in this study, it was more effective to use the BP than the TP model to improve sport-related performances of high level handball players.

However, it should be noted that the different philosophies of training of the 2 models have an impact on the intensity of the training and this could partially explain the different results obtained. In addition, future studies should examine the impact of different periodization models on the locomotive and technical activities during handball matches.

Practical Applications

In modern sports, it is crucial for coaches to select the most efficient and applicable periodization model to reach their goals and obtain peak performances at the right moment. To achieve this, our study suggests that concentrated training stimuli on 2 physical abilities in each mesocycle were more effective than mixed, multitargeted training. In particular, block periodized training program led to greater improvements on selected handball performance variables than a traditional periodized training program Furthermore, a BP approach would avoid the negative interactions of training at the same time different physical abilities, such as endurance and strength that induces conflicting training responses, as it seems to be the case in a TP approach.

The findings of this study suggest that a BP design could be a more useful strategy to achieve greater improvements in variables related to handball performance.

References

1. Bakken, TA. *Effects of Block Periodization Training Versus Traditional Periodization Training in Trained Cross Country Skiers [master's thesis].* Stokholm, Sweden: Swedish School Sport Health Sciences, 2013.
2. Breil, FA, Weber, SN, Koller, S, Hoppeler, H, and Vogt, M. Block training periodization in alpine skiing: Effects of 11-day HIT on VO_{2max} and performance. *Eur J Appl Physiol* 109: 1077–1086, 2010.

3. Bartolomei, S, Stout, JR, Fukuda, DH, Hoffman, JR, and Merni, F. Block vs. weekly undulating periodized resistance training programs in women. *J Strength Cond Res* 29: 2679–2687, 2015.
4. Buford, TW, Rossi, SJ, Smith, DB, and Warren, AJ. A comparison of periodization models during nine weeks with equated volume and intensity for strength. *J Strength Cond Res* 21: 1245–1250, 2007.
5. Chelly, M, Hermassi, S, and Shephard, RJ. Relationships between power and strength of the upper and lower limb muscles. *J Strength Cond Res* 24: 1480–1487, 2010.
6. García-Exposito, M, Alcaraz-Ramón, PE, Ferragut-Fiol, C, Manchado, C, Abraldes-Valeiras, AJ, Rodríguez-Suárez, N, and Vila-Suárez, H. Body composition and throwing velocity in elite women's team handball. *Cult Cienc Y Deport* 6: 129–136, 2011.
7. García-Pallarés, J, García-Fernández, M, Sánchez-Medina, L, and Izquierdo, M. Performance changes in world-class kayakers following two different training periodization models. *Eur J Appl Physiol* 110: 99–107, 2010.
8. Gorostiaga, EM, Granados, C, Ibáñez, J, and Izquierdo, M. Differences in physical fitness and throwing velocity among elite and amateur male handball players. *Int J Sports Med* 26: 225–232, 2005.
9. Gorostiaga, EM, Granados, C, Ibáñez, J, González-Badillo, JJ, and Izquierdo, M. Effects of an entire season on physical fitness changes in elite male handball players. *Med Sci Sports Exerc* 38: 357–366, 2006.
10. Gorostiaga, EM, Izquierdo, M, Iturralde, P, Ruesta, M, and Ibañez, J. Effects of heavy resistance training on maximal and explosive force production, endurance and serum hormones in adolescent handball players. *Eur J Appl Physiol Occup Physiol* 80: 485–493, 1999.
11. Granados, C, Izquierdo, M, Ibañez, J, Bonnabau, H, and Gorostiaga, EM. Differences in physical fitness and throwing velocity among elite and amateur female handball players. *Int J Sports Med* 28: 860–867, 2007.
12. Granados, C, Izquierdo, M, Ibáñez, J, Ruesta, M, and Gorostiaga, EM. Are there any differences in physical fitness and throwing velocity between national and international elite female handballl players? *J Strength Cond Res* 27: 723–732, 2013.
13. Helgerud, J, Engen, LC, Wisløff, U, and Hoff, J. Aerobic endurance training improves soccer performance. *Med Sci Sports Exerc* 33: 1925–1931, 2001.
14. Hoff, J and Almasbakk, B. The effects of maximum strength training on throwing velocity and muscle strength in female team-handball players. *J Strength Cond Res* 9: 255–258, 1995.
15. Hoffman, JR, Ratamess, NA, Klatt, M, Faigenbaum, AD, Ross, RE, Tranchina, NM, MCCurley, RC, Kang, J, and Kraemer, WJ. Comparison between different off-season resistance training programs in Division III American college football players. *J Strength Cond Res* 23: 11–19, 2009.
16. Issurin, V. Block periodization versus traditional training theory: A review. *J Sports Med Phys Fitness* 8: 65–75, 2008.
17. Issurin, V, Timofeyev, V, Sharobajko, I, and Zemliakov, D. *Particularities of Annual Preparation of Top-Level Canoe-Kayak Paddlers During 1984–1988 Olympic Cycle. Scientific Report.* Leningrad, Russia: Research Institute for Physical Culture, 1988.
18. Kraemer, WF, Ratamess, N, Fry, AC, Triplet McBride, T, Koziris, LP, Bauer, JA, Lynch, JM, and Fleck, SJ. Influence of resistance training volume and periodization on physiological and performance adaptations in collegiate women tennis players. *Am J Sports Med* 28: 626–708, 2000.
19. Manchado, C, Hoffmann, E, Valdivielso, FN, and Platen, P. Physiological demands in female handball: demands and heart rate during matches of the German national team. *Dtsch Z Sportmed* 58: 368–373, 2007.
20. Manchado, C, Tortosa-Martínez, J, Vila, H, Ferragut, C, and Platen, P. Performance factors in women's team handball: Physical and physiological aspects-A review. *J Strength Cond Res* 27: 1708–1719, 2013.
21. Manchado, C, Pers, J, Navarro, F, Han, A, Sung, E, and Platen, P. Time-motion analysis in women's team handball: Importance of aerobic performance. *J Hum Sport Exerc* 8(Suppl l): 376–390, 2013.
22. Marques, MC, van den Tillaar, R, Vescovi, JD, and Gonzalez-Badillo, JJ. Relationship between throwing velocity, muscle power, and bar velocity during bench press in elite handball players. *Int J Sports Physiol Perform* 2: 414–422, 2007.
23. Massuça, LM, Fragoso, I, and Teles, J. Attributes of top elite team-handball players. *J Strenght Cond Res* 28: 178–186, 2014.
24. Matveyev, LP. *Problem of Periodization the Sport Training.* Moscow, Russia: Fizkultura i Sport, 1964.
25. Ozolin, ND. *The Modern System of Sport Training.* Moscow, Russia: Fizkultura i Sport, 1970.
26. Painter, KB, Haff, GG, Ramsey, MW, McBride, J, Triplett, T, Sands, WA, Lamont, HS, Stone, ME, and Stone, MH. Strength gains: Block versus daily undulating periodization weight training among track and field athletes. *Int J Sports Physiol Perform* 7: 161–169, 2012.
27. Povoas, SCA, Seabra, AFT, Ascensao, AMR, Magalhaes, J, Soares, JMC, and Rebelo, ANC. Physical and Physiological demands of elite team handball. *J Strength Cond Res* 26: 3366–3376, 2012.
28. Ramos-Veliz, R, Requena, B, Suarez-Arrones, L, Newton, RU, and Saez de Villarrreal, E. Effects of 18-week in season heavy-resistance and power training on throwing velocity, strength, jumping, and maximal sprint swim performance of elite male water polo players. *J Strength Cond Res* 28: 1007–1014, 2014.
29. Ronnestad, BR, Hansen, J, and Ellefsen, S. Block periodization of high-intensity aerobic intervals provides superior training effects in trained cyclists. *Scand J Med Sci Sport* 24: 34–42, 2014.
30. Sleivert, G and Taingahue, M. The relationship between maximal jump-squat power and sprint acceleration in athletes. *Eur J Appl Physiol* 91: 46–52, 2004.
31. Van den Tillaar, R and Ettema, G. Effect of body size and gender in overarm throwing performance. *Eur J Appl Physiol* 91: 413–418, 2004.
32. Verkoshansky, JV. *Fundamentals of special Strength Training in Sport [in Russian].* Mocow, Russia: Fizkultura i Sport, 1977.
33. Vila, H, Manchado, C, Rodriguez, N, Abraldes, JA, Alcaraz, PE, and Ferragut, C. Anthropometric profile, vertical jump, and throwing velocity in elite female handball players by playing positions. *J Strenght Cond Res* 26: 2146–2155, 2012.
34. Wilson, JM, Marin, PJ, Rhea, MR, Wilson, SMC, Loenneke, JP, and Anderson, JC. Concurrent training: A meta-analysis examining interference of aerobic and resistance exercises. *J Strength Cond Res* 26: 2293–2307, 2012.