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ORIGINAL RESEARCH PAPER

ANALYSIS OF TRAINING VOLUME AND METHODOLOGY FOR HIGH-CLASS CANOE SPRINT ATHLETE – A CASE STUDY

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Abstract

Historically in canoe sprint as predominant abilities have been considered endurance and strength. As the sport develops, the often-changing competition programme in Olympic games and international championships with short and high-speed distances added, speed and power become also very important. The aim of this study is to give a detailed description about the training loads and volume and, in addition, to discuss the training methodology (strength training impact in total training amount) for high – class canoe sprint athlete (preparing and racing in the 200m distance). The research person is a medallist and participant of European and World championships. To study the research subject, the document analysis in form of training diary was used. The analysis was divided in three full training year cycles in one-year periods (macrocycles) from September to the following years September. In total 1119 workouts were analysed. In addition, the athletic and sport's specific training forms were distinguished. The athletic strength training was defined as: athletic strength ≥ 80% one repetition maximum (≥ 80% 1RM); athletic strength 60-70% 1RM; athletic strength speed oriented 60 – 70% 1RM; general physical fitness (GPF); statodynamic strength training. The specific strength was defined as: paddling with resistance; paddling with the additional weight in the boat; paddling from boat's standing position; continuous paddling in sports zone II (heart rate of 125 – 140beats/min) with certain maximum strength manifestation in strokes. The total training volume in megacycle of the high-class canoe sprint athlete was 1211h, where the largest part (815.9h) consisted of athletic strength and sport's *specific strength. Research showed a total part of 54% (which corresponded to 235.9h) of strength expression training forms from the total training volume.*

Key words: *Canoe sprint, training load, strength training, specific strength training.*

Introduction

Athletic performance in any sport is affected by combinations of bio-motor abilities, where the three main bio-motor abilities are strength, speed, and endurance (Bompa & Buzzichelli, 2018; Zatsiorsky, 1995, 2006; Konrads, 2002). Many kinds of sports can be classified according to their predominant bio motor ability. Historically in canoe sprint predominant abilities have been considered endurance and strength. As the sport develops, the often-changing competition programme in Olympic games and international championships with short distances added, speed and power become very important. Modern canoe sprint is characterized by high intensity, a tight competition schedule (April to August) and specialization in a particular discipline. By specialization we mean adapting the training of athletes to a specific distance and boat class. If before the 2008 Beijing Olympic Games the athlete often competed in several disciplines and boat classes, then with the next Olympic cycle this trend has changed, and athletes specialize in a specific distance and a specific boat class. This is due to changes in the competition program, which makes it difficult to start in several disciplines. From the International Canoe Federation (ICF), this has been done with the aim of increasing rivalry – bigger the number of participants in certain disciplines and improved athletic performance. Therefore, higher, and higher demands are placed on the physical, technical, tactical, and psychological training of athletes.

Appropriate force is required to move the body and reach the required speed. When paddling at higher speeds, the boat has less water resistance due to the reduced draft of the boat or the reduced surface contact area due to the reduced draft. It is not possible to reduce the water resistance to the hull of the boat to obtain a higher speed, but the athlete's strength can be increased (Szanto, 1999). Strength plays an important role in canoe sprint without the development of strength it is not possible to achieve high results. A strong relationship between force and speed has been demonstrated in the following studies (Costill, Miller, Myers, Kehoe & Hoffman, 1968; Vandewalle, Peres, Heller, Panel & Monod, 1987; Young, Mc Lean & Ardagna, 1995; Bret, Rahmani, Dufour, Messonnier & Lacour, 2002; Cronin & Hansen, 2005; Giroux, Rabita, Chollet & Guilhem, 2016). According to Bompa and Buzzichelli, strength and the ability to perform high power (i.e., large force development at high speed) are important determinants of performance in many sports. Research shows that strength and power are also important in endurance sports, such as long-distance running (Paavolainen, Hakkinen, Hamalainen, Nummela & Rusko, 1999; Jung, 2003) and cross-country skiing (Paavolainen, Hakkinen & Rusko, 1991; Hoff, Helgerud & Wisloeff, 1999; Hoff, Gran & Helgerud, 2002; Østerås, Helgerud & Hoff, 2002). The study by Rønnestad and Mujika (2014), which showed an improvement in the economy of running and cycling and an improvement in performance during the endurance training process, including maximum strength training. Strength and power performance also affect agility. Athletes with better strength and power scores perform better in agility tests (Peterson, Alvar & Rhea, 2006). Given that strength and power have such an impact in many sports, it is important for coaches and athletes to understand how developing these skills affects performance, and to understand the basic guidelines for strength training. According to Bompa and Buzzichelli physiological adaptation of the neuromuscular system can be achieved by a seven-phase model – anatomical adaptation, hypertrophy, maximal force, conversion, maintenance, termination, and compensation. Depending on the physiological requirements of the sport, the periodization of strength training involves at least four of these phases – anatomical adaptation, maximal force, conversion to specific force (power or strength endurance) and maintenance (Bompa & Buzzichelli, 2018).

However, most of the research does not give total amount of training load in hours, where each research has its own countifying system and one of the biggest problems is that amount that athletes have paddled has been counted in kilometres, but amount of athletic or other workouts have been expressed in hours. The information above defines the problem of our research – what is a role of strength training in canoe sprint, specializing in 200m discipline. How large is it? And how substantially is its impact on the total training volume in macrocycle (one year period) and even megacycle (three-year period)? What tools can be used to develop strength and power? There are studies in canoe sprint that reflect training load and its content (Zamotin & Sinjavin, 2018; García-Pallarés, Sánchez-Medina, Pérez, Izquierdo-Gabarren & Izquierdo, 2010; Vishnjakov, 2014; Verlin, 2015; Zhurauskij & Shantarovic, 2016a; Zhurauskij & Shantarovic, 2016b; Englert & Kiesler, 2009; Buchek & Hamar, 1998; Issurin, 2008; Li, 2015).

Material and methods

The research person was a European and World championships medallist. At the beginning of the research subject was 22 years of age, height – 191.2cm, weight – 93.1kg. With 7 years of international competition experience and 12 years of total training experience in canoe sprint. The permission of the Ethics Commission of Latvian Academy of Sport Education was received for this study.

To analyse and summarize available materials the analysis of documents was used. The method included analysis of training diaries (daily training diary and training camp diary) and digital document analysis (Garmin Connect digital diary). The information from the sports watch about each workout was synchronized with both the mobile phone application and the windows application on a computer, and the information obtained can be viewed in the Garmin Connect digital diary mentioned above. Synchronization is possible either in the presence of a wireless Internet connection (Wi-Fi) or via a Bluetooth wireless connection. The analysis of the training process was started from September 2018. In sports, the markers of the year are also planned and listed along with the main annual competitions (Issurin, 2010). In kayaking, a typical macrocycle usually lasts from August to the following years August. So, the research took 3 full training years (periods) from September till September. During research period subject participated in 10 international races and in 8 cases finished in top 8 places (A finals respectively). A total of 1119 workouts were analysed. All workouts were summarized using the Microsoft add-in Excel (Figure 1). The following information was collected for the analysis of the content of the training process (columns indicators were numbered, see number in the brackets behind indicator):

1. Numbering of training sessions (1)
2. Days of the week (2)
3. Date (3)
4. Content of the training session (as wide as possible, the mentioned exercises are listed, their duration, intensity, duration of rest breaks, number of repetitions, number of passes, number of series, aids used, etc.) (4)
5. Average heart rate (HR) during training session (5)
6. Maximum HR during exercise (6)
7. Total training time (in minutes, later transferred to hours) (7)
8. Total amount completed in the training session (in kilometres) (8)
9. Average training session speed (km/h) (9)
10. Maximum indicated speed in training session (km/h) (10)

1	2	3	4	5	6	7	8	9	10
		4.12.	Off day						
65	***Tr***	5.12.	Paddling: 20"(p40"),20"X8sēr.; 500m pace	126	174	122:56:00	19,43	9,5	20,4
66			*Paddling: 7x5' 2.zone (last min HR till 160bpm); with additional weight 10kg*	127	164	90:01:00	15,01	10	14,8
67			Athletic strength: Speed oriented 60-70% 1RM: 3 exercises, 4 sets per 15"/20" repetitions.			45:00:00			
68	***Ce***	6.12.	**Paddling: 4x20"(p40")X8series; resistance - 2 tennis balls**	132	172	118:41:00	17,91	9,1	13,9
69			Athletic strength: ≥80% one repetition maximum (1RM): Deadlift 8x130kg, incline Bench press 8x70kg, core exercises			90:00:00			
70	***Pk***	7.12.	Paddling: 10"(p50"),10"X9; 200m pace	130	175	136:15:00	19,19	8,5	22,2
71			*Paddling: 10'(p2'),8'(p2'),6'(p2'),4'(p2'),2' ; 2.zone; with additional weight 5kg*	122	137	97:36:00	15,75	9,7	13,2
		8.12.	Off day						
72	***Sv***	S	Paddling: 5x15"(p2"45")X3 sēr; P7'; Tempo: 90 s/min	121	161	104:10:00	15,8	9,1	20,1
73			*Paddling: 8X6' (on each 2'30" -->30" with Max strong stroke and pause; with additional weight 10kg*	125	151	96:52:00	15,73	9,8	13,8
74			Athletic strength: Statodynamics . 3 exercises (iccline bench press,squats, behind neck pull-down) X2series; 30"(p30"),30"(p30"),30"(p30"),30"(p30"),30";statodynamic regime; 40-60 % 1RM			80:00:00			

p – pause between repetitions; P – pause between series; HR – heart rate; 1RM – one repetition maximum

Figure 1. An example of a training process table summary created by the author. For explanation see text below.

By summarizing the training process, it was also necessary to mark free days, competition days, as well as to organize the analysis of the training process content. For example, the Figure 1 shows a holiday in light grey shade, making it easier to see smaller microcycles. In the column number one training sessions were numbered. The column number 2 marked the days of the week, in upper figure letters marked in bold, underlined and italic indicated that the subject was in a training camp. The column number 4 reflected the content of the training session, it this case different marked letters reflect different training forms, for example, session 68, marked in bold letters was sport's specific strength training form – paddling with the resistance. Sessions 66.71 and 73 are marked in italic letters, because these were sport's specific training form – paddling with additional weight in the boat. Columns number 5 and 6 reflected average and maximum HR of the training sessions. Column 7 reflected total time of training session. Column 8 reflected total distance completed in training session. Columns 9 and 10 reflected speeds in training session (average and maximum).

Overall, in our research of high-class canoe sprint athlete's training methodology and volume the training process was divided in three basic training forms:

1. Specific training load (paddling on the water).
2. Non-specific training load (other physical activities except paddling and

athletic strength).
3. Athletic Strength.

Non-specific training load included following training forms:
1. Bicycle.
2. Running.
3. Swimming.
4. Cross-country skiing.
5. Paddling on ergometer.
6. Roller-skiing.

By summarizing the training process, the methodology of strength development was divided in two forms: athletic strength and sport's specific strength, respectively. Canoe sprint due to its specifics, provides opportunities to use strength tools in sports-specific training on the water, for example, putting an additional weight in the boat, putting a rope with added tennis balls around the boat's hull (hydraulic resistance), making a sprint from boat's standing position, making a continuous paddling with certain maximum strength manifestation in strokes etc.

Athletic strength in following training forms were distinguished:
1. athletic strength ≥80% 1RM,
2. athletic strength 60 – 70% of 1RM,
3. athletic strength speed oriented 60 – 70% 1RM,
4. athletic strength - general physical fitness (GPF),
5. statodynamics (40 – 60% 1RM 3 – 5x per 20 – 40" (p20 – 40"))

By analysing the forms used in the training process in the specific sports trainings (on the water), training sessions were distinguished in which the exercises were used with the aim to develop strength and forms of its expression. According to the author's summary, the following forms were presented:
1. paddling with resistance,
2. paddling with the additional weight in the boat,
3. paddling from boat's standing position*
4. continuous paddling in sports zone II with certain maximum strength manifestation in strokes*

*The last two are marked with an asterisk because these shapes are fixed when no resistances or extra weights are used. If such forms are executed with resistance or with added weight, the executed load is counted towards the first two forms.

Other sport specific forms were:
1. paddling CDT (*continuous distance training)*.
2. paddling (rest activities).

Furthermore, when the main analysis of training diaries was completed, it was divided into three parts (the macrocycles). Each macrocycle was divided into mesocycles and the total volume for sport's specific, non-specific, and athletic strength was obtained. In our research those were the basic forms for further analysis, also this classification type is like a training volume classification made by Norwegian researchers in cross-country skiing (Tonnessen et al., 2014).

To analyse and summarize the training volume and to distinguish the strength training and sport's specific strength training all three macrocycles were explored separately and mesocycle (approximately one month time) was chosen as smallest time for counting the different loads. (See table 1).

Table 1

Primary training load list table in the first mesocycle

Training forms	Minutes	Hours	Kilometres	Count
Bicycle	302:40:00	5	90.43	11
Running	52:57:00	0.88	7.66	2
Athletic Strength	295:14:00	4.9		3
Paddling	389:42:00	6.5	65.11	5
Total time (h)		17.3		

This mesocycle basically consisted of four training forms – two of the non-specific forms were cycling and running, the third was athletic strength and the fourth was paddling (specific load). To complete the aim, there was a need for much wider allocation of the training forms (see table 2). The basic training volume forms were to be divided in more detail, as seen in table 2, for example, such non-specific training forms as bicycle continuous distance training (Bicycle CDT) and running CDT were divided.

Table 2

Detailed training load list table in the first mesocycle

	Minutes	Hours	Kilometres	Count
Bicycle CDT	302:40:00	5	90.43	11
Running CDT	52:57:00	0.88	7.66	2
Athletic strength 60-70% 1RM	120:00:00	2		1
Athletic Strength GPF	175:14:00	2.9		2
Paddling CDT	389:42:00	6.5	65.11	5
Total time (h)		17.3		

CDT – continuous distance training

For each mesocycle, the total performed training volume (h) was recorded (see table 3) for basic training forms – specific work, non-specific work and athletic strength and total training volume of mesocycle was determined. The sport's specific strength load on the water was also listed separately so that it's total share in the training volume could be estimated later.

Results

Total training volume for the first macrocycle was 419.7h. Specific training form was 251.8h (which corresponded to 60% of the total training volume), athletic strength was 83.6h (which corresponded to 20% of the total training volume) and non-specific training form was 84.3h (which corresponded also to 20% of the total training volume). Specific training form with expression of strength was 135.8h (corresponded to 32% from total training volume). Overall training volume relationship in first macrocycle showed, that trainings with strength expression dominated through whole training process (see figure 3).

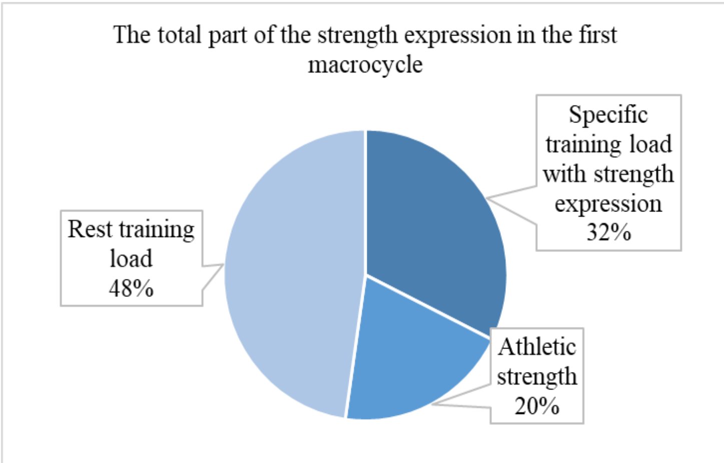

Figure 3. The total volume of training with strength expression in the 1st macrocycle of the athlete

Total training load for the second macrocycle was 461.4h. Specific training form was 296.5h (which corresponded to 64.3% of the total training volume), athletic strength was 95.2h (which corresponded to 20.6% of the total) and non-specific training form was 69.7h (which corresponded to 15.1% of the total). Specific training form with expression of strength was 161h (which corresponded to – 34.9% of the total). Overall training volume relationship in second macrocycle showed, that trainings with strength expression dominated through the whole training process (see figure 4).

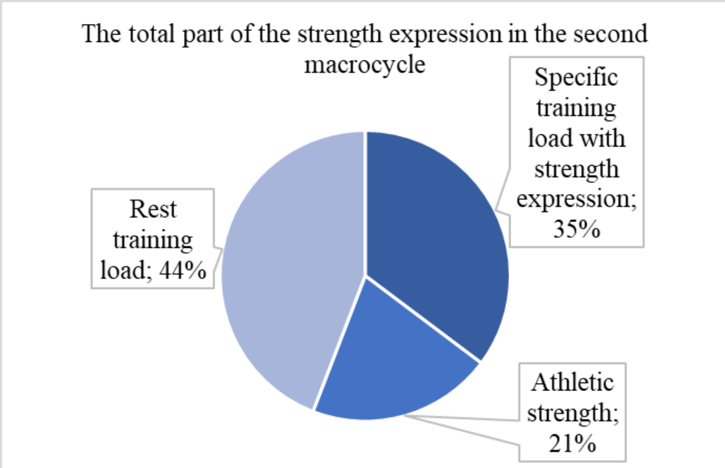

Figure 4. The total volume of training with strength expression in the 2nd macrocycle of the athlete

Total training volume for the third macrocycle was 440.9h. Specific training form was 292.1h (which corresponded to 66.3% of the total training volume), athletic strength was 68.3h (which corresponded to 15.5% of the total) and non-specific training form was 80.5h (which corresponded to 18.2% of the total). Specific training form with expression of strength was 163.6h (which corresponded to – 37.1% of the total). Overall training volume relationship in third macrocycle showed, that trainings with strength expression dominated through whole training process (see figure 5).

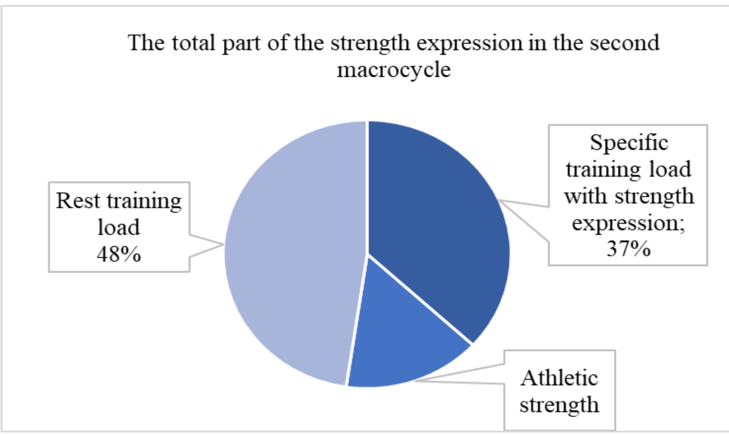

Figure 5. The total volume of training with strength expression in the 3rd macrocycle of the athlete

During three-year period the total training volume was 440.7±20.9h an average per macrocycle. From that 280.1±24.6h was dedicated for sports specific load – paddling on the water (which corresponded to 64% average per macrocycle). For athletic strength it was 82.4±13.5h average (which corresponded to 19% average per macrocycle). For non-specific training it was 78.2±7.6h average (which corresponded to 18% average per macrocycle). However, the total training volume of sports-specific strength trainings was 153.5±15.4h average per macrocycle (which corresponded to 35% average per macrocycle). By summarizing the total amount of training volume with strength expressions – athletic strength together with specific strength, research showed a total part of 54% average per macrocycle from the total training volume.

Discussion

Research on training volume and its methodology in canoe sprint are limited (Zamotin & Sinjavin, 2018; García-Pallarés, Sánchez-Medina, Pérez, Izquierdo-Gabarren & Izquierdo, 2010; Vishnjakov, 2014; Verlin, 2015; Zhurauskij & Shantarovic, 2016a; Zhurauskij & Shantarovic, 2016b; Englert & Kiesler, 2009; Buchek & Hamar, 1998; Issurin, 2008; Li, 2015). Most of the research does not give total amount of training volume in hours – each research had its own countifying system. One of the biggest problems is that the amount that have been paddled by athletes has been counted in kilometres, but amount of the athletic strength or other workouts have been expressed in hours. Most of these research does not reflect the total training volume in hours. Moreover, completed research in eastern Europe provide a quite detailed information of training volume and its methodology, but most of the times amount of the sports-specific volume was counted in kilometres, however, for example, athletic strength was counted in hours. And to get the total training volume in hours, you must do your own mathematics, which will not be exact. In research by Zamotin and Sinjavin (2018) authors looked on the Russian national team athletes, who raced 1000m, training amount on the water was reflected. On-water trainings were divided by five intensity zones – depended on heart rate and speed at the special on-water physical tests (5km and 1250m) (Zamotin & Sinjavin, 2018). They reported a total amount of 3500km done by athletes during whole year macrocycle. Researcher Vishnjakov (2014) in his study reported amount of 4115km for national team members in 1000m. However, he also reported high amount of specific work also for youth and juniors – 4416.5km and 3856.5km accordingly. In case of our research, we can compare athletic strength, also including generally developing exercise – those are counted in hours. For men’s team the total amount is 183h (Vishnjakov, 2014). In our case those are more than a half less hours – 82.4. Verlin (2015) brought forward a five-intensity zone model for planning training load and volume for high-class canoe sprint athletes, according to speed form 200m distance test and lactate acid in the blood. However, this research also reported very high amount of specific work for 200m canoe sprint athletes. Sprinters should manage 3500 – 4000km per year. If we compare our subject, his highest number of paddled kilometres during the time (seasons) research was done was around 2600km. Zhurauskij and Shantarovic (2016a, b) reported even higher numbers of paddled kilometres, an average of 5111.16km per season. However, both research completed on Belarusian national team, in these cases there were no separation of 200m specialists or 1000m specialists. They also presented a five-zone planning model according to lactate acid in blood and sprint exercise time limitation. Interesting, that five zone planning model of Verlin (2015) differed from Zhurauskij and Shantarovic (2016a, b). However, the summarizing of non-water training load was similar in those studies. In case of our research, we compared athletic strength (also including generally developing exercise) they were counted in hours. Zhurauskij and Shantarovic (2016a, b) reported several 90.33h, compared to our research 82.4h.

According to Buchek and Hamar (1998) they reported similar total number of training load per season. 510h versus our subjects 440.7h, of whom water training took 58% (295.8h) versus our subjects 64% (280.1h), athletic strength took 28% (142.8h) versus our subjects 19% (84.2h) and other activities took 14% (71.4h) versus our subjects 18% (72.8h). The percentage of specific training load were very similar, also non-specific training load. However, athletic strength and total training load are reported higher by Buchek and Hamar (1998).

Research by Engler and Kiesler (2009) gave an insight in Germans national team training load totals from seasons of 2003–2008. The total training volume per season was reported around 800 h, from that 400–550h was specific training load. By closing to 2008 Olympics, the amount of specific training increased. But this was also research on 500m and 1000m athletes. Only from 2009, the 200m meter distance become Olympic. Also, when we look on our research – both specific training volume (similar as in research by Engler and Kiesler (2009)) and specific strength training volume part from the total training volume increased.

Very detailed information was provided in research done by García-Pallarés and colleagues (2010). They were investigating physiological effects of tapering and detraining in world-class canoe sprint athletes – 14 Spanish national team kayakers. Although this study analysed changes in neuromuscular, body composition, and endurance markers during 4 weeks of tapering and subsequent 5 week of reduced training or training cessation, it provided very detailed information about total training load and its content. They reported total amount of 4415±374km average paddled per season. That is more than reports Zamotin and Sinjavin (2018) and Verlin (2015). But it is close to amount reported by Vishnjakov (2014). However, it was less than the amount reported by Zhurauskij & Shantarovic (2016a, b) – they reported a total paddled average amount of 5115km per season, which is by far the biggest amount reported in studies about canoe sprint in last 20 years. Historically there were also bigger amounts reported. By comparing training load amounts between our research and Spanish research they differed, but in case, that our subject specialised in 200m distance and they according to period when research was published, for 500m and 1000m distances, not so much. Average specific work 280.1h versus 312.6h; athletic strength 82.4h versus 114.6h.

Nowadays the sharing of sensitive information in sport's training volume and methodology is increasing, also one of the best canoe sprint coaches and sport science practitioner Alexander Nikonorov gave an insight in canoe sprint training process for 200m distance. We must mention that his athletes won the London 2012 and Rio 2016 Olympics in K1 200m and in K2 200m took bronze and silver. "I remember times when training volume was 1500 h; my athletes from London and Rio did around 600h." (Nikonorov, 2020a, b). According to him they tried to do as much as they could, they simply could not do more because of the intensity and of a lot of power development work.

As we see, there are a lot of differences in training volume of high-class canoe sprint athletes. However, in last two decades there is an overall tendency to decrease the total volume of training, but to increase the intensity to get athletes better in their main discipline – distance and boat class they are specializing in. The athletic strength in studies usually consisted of 20% till 30% from total training volume. In our research it was similar – an average of 19% from total volume per season. Considering that 200m demonstrate the highest power outputs, this indicator should be higher. And as said by Nikonorov (2020), one of the most important parts of the training process is the application in the boat. How to transfer the maximum strength and power you have developed through athletic strength to the paddling. For example, top class athletes can do a maximum bench pull of 160 – 180kg but in the paddling in pulling phase athletes can pull only 37kg, the rest of the force goes different ways. As reported in literature, to maintain the work athletes do in canoe sprint, a high strength endurance in combination with relative high power is needed (Szanto, 1999; Krauksts, 2003). To enhance performance in muscle endurance sports, maximal strength training should be followed by a specific combination of metabolic and special strength training to prepare the body for the needs of the sport (Платонов, 2004; Bompa & Buzzichelli, 2018). Researchers Bompa and Buzzichelli (2018) proposed a seven-phase model corresponding to the physiological adaptation of the neuromuscular system. These seven phases are anatomical adaptation, hypertrophy, maximal force, conversion, maintenance, termination, and compensation. Depending on the physiological requirements of the sport, the periodization of force involves at least four of these phases – anatomical adaptation, maximal force, conversion to specific force (power or strength endurance) and maintenance (Bompa & Buzzichelli, 2018).

With reference to all the above, the importance of the transferring the strength and power to paddling on the water was confirmed. And as we clarified in our research in training process of our subject, a grate part of sports specific strength training was conducted, and four specific strength training forms were distinguished.

Conclusions

During three-year period the total training load was 440.7h average per macrocycle. For developing the strength two basic forms were used:

1. Athletic strength (all workouts with strength expressions on the ground).
2. Specific-strength workouts when paddling on the water.

For athletic strength it was 82.4h average (19% from total training volume). However, the total training load of sports-specific strength trainings was 153.5h average per macrocycle (35% from total training volume).

The total amount of training volume with strength expressions – Athletic strength + Specific strength, research showed a total part of 54% (which corresponds to 235.9h per macrocycle) from the total training volume.

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