EFFECTS OF TRAINING AND DETRAINING ON MUSCLE STRENGTH IN ROWERS

Nebojša JANJIĆ, Mina MARIČIĆ, Andrea ZUBNAR, Vedrana KARAN, Miodrag DRAPŠIN and Aleksandar KLAŠNJA

Introduction

Rowing was first used as a means of transport in ancient Egypt, Greece and Rome. As a sport, it probably began in England, in the 17th and early 18th centuries, with the Oxford - Cambridge university boat race, which was inaugurated in 1828. Rowing is one of the oldest Olympic sports. Today, there are fourteen boat classes which race at the Olympics [1].

While rowing, the human body works as the engine to propel the rowing boat across the water. During each stroke, the athlete applies the equivalent of a 40 to 45 kg load to the oar handle in each of the 220 to 250 strokes that occur during the race [2]. Rowing is a sport which requires a well conditioned body to operate at a high performance level during periods of training and competition. This sport is one of the few non-weight bearing sports that exercises all the major muscle groups, including quadriceps, biceps, triceps, latissimus dorsi, gluteus and abdominal muscles. The sport also requires strong core balance, physical strength, flexibility and cardiovascular endurance [3, 4]. The general training objectives in rowing are to increase maximum oxygen utilization, increase strength endurance, increase maximum strength, improve the efficiency of rowing technique, and improve flexibility and coordination. Strength training is an integral part of the structured regimen.

Summary

Introduction. Annual and periodized training protocols significantly affect the muscle adaptation in rowers. Considering that the main goal of the training period is increasing specific muscle strength and of detraining period increasing general strength and active rest, the aim of this study was to compare the strength of different muscle groups between training and detraining periods. Material and Methods. The study was conducted at the Department of Physiology, Faculty of Medicine Novi Sad, and it included 34 male and female rowers, 15 to 18 years of age. The muscle strength was measured using a Concept 2 DYNO dynamometer. The strength of the arm extendors and flexors, as well as the leg extensors was measured twice, at the end of the competition season (peak of performance) and before the beginning of the preparation season (after detraining). Results. A statistically significant decrease was found in absolute and relative muscle strength, flexor and arm extensor contraction rate, as well as relative leg extensor strength and contraction rate during the training and detraining periods (p < 0.05). No difference was found in the absolute leg extensor power between the two measurements (p > 0.05). Conclusion. Periodization of the annual training program in rowers has a higher impact on differences in the upper limb muscle adaptation, compared to lower limb muscles in terms of absolute strength.

Key words: Adaptation, Physiological; Muscle Strength; Water Sports; Athletic Performance; Muscle Strength Dynamometer; Resistance Training

Sažetak

Uvod. Periodizovani trennažni protokol značajno utiče na mišićnu adaptaciju veslača. S obzirom na to da je glavni cilj perioda treninga povećanje specifične mišićne snage, a perioda detrinerta povećanje opšte snage i aktivitan odmor, cilj ovog istraživanja bio je da se snage raznih mišićnih grupa uporede između perioda treninga i detrinerta. Materijal i metode. Istraživanje je sprovedeno na Zavodu za fiziologiju Medicinskog fakulteta u Novom Sadu. Uključeno je 34 veslača oba pola, starosti između 15 i 18 godina. Mišićna snaga je merena dva puta, na kraju takmičarske sezone (vrh performansi) i pre početka sledeće takmičarske sezone (nakon detrinerta). Rezultati. Dokazano je statistički značajno smanjenje apsolutne i relativne mišićne snage, brzine kontrakcije fleksora i ekstenzora ruku, kao i relativne snage i brzine kontrakcije ekstenzora nogu između perioda treninga i detrinerta (p < 0.05). Nije nađena razlika u apsolutnoj snazi ekstenzora nogu između dva merenja (p > 0.05). Zaključak. Periodizacija godišnjeg treninga veslanja ima veći uticaj na variranje adaptacije gornjih ekstremiteta u poređenju sa donjim ekstremitetima u smislu apsolutne snage. Ključne reči: fiziološka adaptacija; mišićna snaga; vodeni sportovi; sportski učinak; dynamometar; trening otpora

University of Novi Sad, Faculty of Medicine Novi Sad
Department of Physiology

Original study
Originalni naučni rad
UDK 612.74:797.12.071.2
UDK 612.74:797.12.071.2
https://doi.org/10.2298/MPNS1908223J
of elite rowers, accounting for 10 – 20% of total training time [5]. During the competitive season, rowers perform strength training with loads between 85 and 95% of their one repetition maximum (1 RM) [6]. Adaptations in strength training are focused on the development and maintenance of the neuromuscular units needed for force production. Neural adaptation dominates in the early phase of neuromuscular development. In the later adaptation phase, muscle protein content increases, and the contractile units begin to contribute the most to the changes in performance capabilities [7, 8].

Detraining has been defined as the partial or complete loss of training-induced adaptations, in response to an insufficient training stimulus. Detraining is closely related to the terms ‘reversibility’ and ‘periodization’. Reversibility is a reduction in the conditioned state of the individual and occurs when the training stimulus is insufficient. Significant conditioning is lost after 2 – 6 weeks of insufficient training. Periodization is a concept which takes into account the fact that it is not possible to train all aspects successfully at once. It also recognizes that cessation or reduction of a training stimulus leads to a decline in specific conditioning [9, 10]. The training program is usually divided into 6 periods: two preparation periods focused on maximum strength, general endurance and muscular endurance; the pre-competition period that focuses on maximum strength, general endurance and muscular endurance; the pre-competition period that focuses on basic specific endurance and rowing technique; two competition periods mainly increasing specific endurance and race preparation, when training reaches “peak” for the championships; and finally, active recovery period [11].

Considering that annual planning and periodization play a great role in muscle adaptation in rowers, the aim of the study was to compare the strength of different muscle groups between training and detraining periods in order to show how periodization affects the adaptation of individual muscle groups.

**Material and Methods**

This prospective study included 34 rowers, male and female, aged between 15 and 18 years. The study was conducted in the period from August to October 2018. All participants were tested twice, first at the end of the competition season, at the peak of their seasonal performance, and second, before the start of the next preparation season – after the period of detraining. All measurements took place in the Laboratory for Functional Diagnostics of the Department of Physiology, Faculty of Medicine Novi Sad. The study was approved by the Ethical Committee of the Faculty. All participants signed written Informed consent forms.

**Abbreviations**

- **RM** – repetition maximum
- **VO$_2$ max** – maximum rate of oxygen consumption

---

**Graph 1.** Absolute (upper panel) and relative (lower panel) strength of different muscle groups measured after the period of training (black bars) and detraining (grey bars). Significant differences between the two periods were found in absolute and relative strength of arm flexors and extensors, and in relative strength of leg extensors. Asterisk (*) indicates the significance at $p < 0.05$.

**Grafikon 1.** Apsolutne (gornji) i relativne (donji) snage mišićnih grupa merenih nakon perioda treninga (crni stubići) i detreninga (sivi stubići). Značajne razlike između snaga u dva meraena perioda nađene su u apsolutnim i relativnim snagama fleksora i ekstrenzora ruku, kao i ekstrenzora nogu. Zvezdica (*) označava značajnost na nivou $p < 0.05$. 

**Anthropometrics.** Body weight and body height were measured using a calibrated, combined weight-height scale, while a measuring tape was used for body circumferences.

**Dynamometry.** The DYNO (Concept 2, Morrisville, VT, USA) dynamometer was used to measure muscle strength and contraction speed. Three groups of muscules were tested at both points in time: arm flexors, arm extensors, and leg extensors. The testing was standardized in such a way that every subject received the same instructions, went through the warm-up of the same duration and intensity, and
was given an opportunity of a pre-test in order to familiarize with the machine. Additionally, starting and ending angles of the extremities were controlled in order to ensure the maximal consistency of the movement. First three contractions were always given as a physical and psychological preparation and the next five maximal contractions were statistically analyzed using a dynamometer in order to provide the mean values as the output. These data were gathered and subsequently analyzed.

Statistical analysis was performed in SPSS Statistics ver. 20. As anthropometric and dynamometric parameters did not violate the assumptions of normality, the means between two measurements were compared using the t-test for dependent samples. All results were expressed as mean ± standard deviation, and the level of significance was set at p < 0.05.

Results

The study included 34 male and female rowers aged 16.5 ± 1 years. Their average height was 182.05 ± 4.5 cm, average weight 74.14 ± 4.68 kg, and they have been training actively for 3.7 ± 1.7 years.

During the detraining period, the strength of arm muscles, both flexors and extensors, decreased significantly when compared to the training period (66.2 ± 10.6 vs. 57.1 ± 12.5 kg in the flexors, p = 0.034; 62.4 ± 10.9 vs. 52.5 ± 15.0 kg in extensors, p = 0.045). Unlike that, the strength of leg extensors was also found to be significantly different (144.6 ± 17.8 vs. 130.4 ± 23.7 kg, p = 0.067) (Graph 1).

The relative strength was calculated by dividing the absolute muscle strength with the body weight at the testing time. Relative strength of arm muscles decreased significantly following the detraining period (0.89 ± 0.14 vs. 0.77 ± 0.14 in the flexors, p = 0.015; 0.84 ± 0.15 vs. 0.7 ± 0.16 in extensors, p = 0.019), as shown in the Graph 1. Such a significant decrease was also found for the relative strength in the leg extensors (1.95 ± 0.24 vs. 1.76 ± 0.28, p = 0.041).

Graph 2 shows that contraction speed decreased significantly after the period of detraining compared to the period of training in all three muscle groups: arm flexors (416.9 ± 32.7 vs. 360.1 ± 47.9 cm/s, p = 0.002), arm extensors (387.6 ± 38.9 vs. 334.8 ± 56.0 cm/s, p = 0.006) and leg extensors (527.8 ± 40.0 vs. 467.9 ± 63.5 cm/s, p = 0.005).

Discussion

In this study, we examined the muscle strength differences in two periods of training and found that absolute and relative strength and velocity of the upper body decreased during detraining. These differences were not found in the lower extremities.

The traditional training periodization, a division of the entire seasonal program into smaller periods was established about sixty years ago, when the knowledge of athletes’ preparation was poor and the scientific background insufficient. To this day, sport science has changed tremendously, while the classical periodization has remained at the same level, offering coaches basic guidelines for structuring and planning the training process [12].

Classical periodization protocol has six integral parts, two preparation periods, pre-competition period, two competition periods and active recovery.

Preparation period 1 focuses on maximum strength and general endurance, while preparation period 2 focuses on general endurance and muscular endurance. Strength training is an integral part of preparations, and it is equally important for novices and seniors. Therefore, authors suggest that it may be wise to prioritize weight-training over the preparation period, as senior rowers are likely to cease strength training when the championships start. In terms of rowing performance, strength training should ideally be done twice a week and should primarily target the lower–body. The volume of weight training exercise should be gradually reduced and intensity increased with time, to manage fatigue as the demands of competitive rowing and training increase progressively [13]. Skeletal muscles have the capacity to adapt according to the type and intensity of physical activity they are required to perform. The onset and degree of adaptation depend on the type, intensity and duration of the training stimulus [14]. During these phases, rowers gain strength in both the upper and lower body. This muscle strength is not specialized for any specific sport discipline or movement and can be assessed by commercial dynamometry. Air-braked isoacceleration dynamometers, such as Concept 2 DYNO,
maintain the same resistance during the movement and measure the maximal force of the contraction expressed in kilograms, power in Watts, work in Joules, and contraction speed in cm/s. This type of assessment is suitable for evaluation of strength progress, especially for junior rowers and talent identification programs for rowing as it decreases the potential risk of injury [15].

The pre-competition period focuses on improvement of basic specific endurance and rowing techniques by replacing the gym with on-water trainings, targeting arm flexors and extensors, chest and back muscles. The competition period with the main goal on increased specific endurance, “super-compensation” effect and race preparation is a period in which the training reaches peak for the championships. This is the period when athletes display their maximal abilities, i.e. strength, endurance or other sport specific performances. Unlike relative maximal strength, absolute maximum strength is a strong determinant of rowing performance. Lawton et al. reported that peak quadriceps strength together with maximum rate of oxygen consumption (VO₂ max) has been found to be a major predictor for 2000-m performance [13]. In our study, leg extensors’ absolute strength at the peak of performance was 144.6 kg, while for arm extensors and flexors it was 66.2 kg and 62.4 kg, respectively. When compared to kayakers tested by Kojić et al., there were no differences in leg extensors’ strength, but kayakers showed better results in the strength of both arm flexors (107.9 kg) and extensors (98.9 kg) [16].

After the championships period, cessation of resistance training is typically associated with a diminished physiological function, reductions in maximal voluntary muscle strength, muscle cross-sectional area and neural drive to the muscle [17]. In contrast, some studies have reported partially preserved gains in dynamic muscle strength when resistance training was followed by 6 – 12 weeks and even 30 – 32 weeks of detraining [18]. Determing the annual protocol, in addition to the preparation for the championships period, it is important to consider lengthening the annual protocol, additional attention should be given to detraining. It should be planned as an active recovery. Since we measured muscle strength twice, once after championships and once after detraining, our results showed that although the strength of arm flexors and extensors decreased significantly (by 14% and 16%, respectively), there were no significant changes in the leg extensors in terms of absolute strength, after the period of detraining. A possible explanation is that during detraining, athletes did not completely cease with physical activities. During their active recovery, rowers worked on improving general strength and endurance by running, targeting leg muscles, and eliminated the gym and specific on-water exercises, targeting arm flexors and extensors. Another explanation could be adaptation of the central nervous system, which is induced together with muscular hypertrophy. As a result, the muscle strength can be maintained longer, even after detraining, since nervous factors do not reverse as fast as muscular hypertrophy [19]. Andersen et al. revealed that quadriceps femoris eccentric strength may remain entirely unchanged even after three months of detraining, while concentric strength of the muscles decreases [20]. Our results showed that the concentric strength of the leg extensors did not decrease significantly. It may be explained by the fact that subjects in the mentioned study entirely ceased physical activity during detraining. Great attention should be paid to detraining, since it represents a very sensitive period for an athlete. It should be used to maintain and perfect the technique, because the sequence, modality and the timing of every movement is of paramount importance for the formation of dynamic stereotype. Well learned and memorized dynamic stereotype is a basis for performing the greatest amount of work per unit time, with the least energy expenditure. Based on such a dynamic stereotype, increase in strength and stamina after detraining leads to excellence in results.

Conclusion

Periodization of the annual rowing training program has higher impact on differences in the upper limb muscle adaptation compared to the lower limb muscles in terms of absolute strength. When planning the annual protocol, additional attention should be given to detraining. It should be planned as an active recovery in order to maintain the previously acquired abilities.

References

1. Nauright J, Parrish C. Sports around the world history, culture, and practice. Santa Barbara: ABC-CLIO; 2012.
2. Harfield PD. Enhancing the mechanical efficiency of skilled rowing through shortened feedback cycles. Loughborough: Loughborough University; 2016.
3. Hosea TM, Hannafin JA. Rowing injuries. Sports Health. 2012;4(3):236-45.
4. Karaba Jakovljević D, Jovanović G, Erić M, Klasića A, Slavić D, Lukač D. Anthropometric characteristics and functional capacity of elite rowers and handball players. Med Pregl. 2016;69(9-10):267-73.
5. Guellich A, Seiler S, Emrich E. Training methods and intensity distribution of young world-class rowers. Int J Sports Physiol Perform. 2009;4(4):448-60.
6. Gee TI, Olsen PD, Berger NJ, Golby J, Thompson KG. Strength and conditioning practices in rowing. J Strength Cond Res. 2011;25(3):668-82.
7. Jones TW, Howatson G, Russell M, French DN. Performance and neuromuscular adaptations following differing ratios of concurrent strength and endurance training. J Strength Cond Res. 2013;27(12):3342-51.
8. Drapiš M, Barak O, Popadić-Gaćeša J, Klasića A, Naumović N, Grujić N. Follow up of some anthropometric and ergonomic parameters during 8 week resistance training. Med Pregl. 2009;62(11-12):505-12.
9. Mujika I, Padilla S. Detraining: loss of training-induced physiological and performance adaptations. Part 1: short term insufficient training stimulus. Sports Med. 2000;30(2):79-87.
10. Godfrey RJ, Ingham SA, Pedlar CR, Whyte GP. Detraining and retraining of an elite rower: a case study. J Sci Med Sport. 2005;8(3):314-20.

11. Tran J, Rice AJ, Main LC, Gastin PB. Profiling the training practices and performance of elite rowers. Int J Sport Physiol Perform. 2015;10(5):572-80.

12. Issurin VB. New horizons for the methodology and physiology of training periodization. Sports Med. 2010;40(3):189-206.

13. Lawton TW, Cronin JB, McGuigan MR. Strength testing and training of rowers: a review. Sports Med. 2011;41(5):413-32.

14. Popadić Gaćeša JŽ. Training for genes – how to design it? Med Pregl. 2017;70(7-8):227-33.

15. Gee TI, French DN, Howatson G, Payton SJ, Berger NJ, Thompson KG. Does a bout of strength training affect 2,000 m rowing ergometer performance and rowing-specific maximal power 24 h later? Eur J Appl Physiol. 2011;111(11):2653-62.

16. Kojić Lj. Komparativna analiza snage ekstenzora i fleksora lakta i anaerobnog kapaciteta kod veslača i kajakaša na mirnim vodama. Godišnjak Fakulteta sporta i fizičkog vaspitanja. 2012;18:37-50.

17. LeMura LM, von Duivillard SP,Andreacci J, Klebez JM, Chelland SA, Russo J. Lipid and lipoprotein profiles, cardiovascular fitness, body composition, and diet during and after resistance, aerobic and combination training in young women. Eur J Appl Physiol. 2000;82(5-6):451-8.

18. Kraemer WJ, Koziris LP, Ratamess NA, Hakkinen K, Triplett-McBride NT, Fry AC, et al. Detraining produces minimal changes in physical performance and hormonal variables in recreationally strength-trained men. J Strength Cond Res. 2002;16(3):373-82.

19. Popadić Gaćeša JZ, Kozić DB, Grujić NG. Triceps brachii strength and regional body composition changes after detraining quantified by MRI. J Magn Reson Imaging. 2011;33(5):1114-20.

20. Andersen LL, Andersen JL, Magnusson SP, Aagaard P. Neuromuscular adaptations to detraining following resistance training in previously untrained subjects. Eur J Appl Physiol. 2005;93(5-6):511-8.