European Journal of Physical Education and Sport Science
ISSN: 2501 - 1235
ISSN-L: 2501 - 1235
Available on-line at: www.oapub.org/edu

DOI: 10.46827/ejpe.v9i4.4666 Volume 9 | Issue 4 | 2023

DIFFERENCES IN PHYSICAL FITNESS PROFILES OF ATHLETES IN CYCLIC ACTIVITIES (RUNNING, CYCLING, BIATHLON)

Ratko Pavlović[1i],
Mensur Vrcić[2],
Nikola Radulović[3]
[1]Faculty of Physical Education and Sport,
University of East Sarajevo,
Bosnia and Herzegovina
[2]Faculty of Sport and Physical Education,
University of Sarajevo,
Bosnia and Herzegovina
[3]Faculty of Sport and
Faculty of Physical Education,
University of Novi Sad,
Serbia

Abstract:
Endurance-type disciplines (running, cycling, biathlon) define the cyclic structure of an athlete's movements, which, in addition to functional parameters, also includes an adequate fitness profile. Based on the detection, analysis and evaluation of these parameters, it is possible to define the fitness profile of the competitors as well as possible mutual differences. The current case study analyzes the fitness profile of competitors of three different disciplines (middle and long distances, cycling, ski biathlon) of top-level competitors, members of national teams. The study was conducted: Uroš Gutić (UG) - runner middle and long distances, member of AK "Sarajevo" and the BIH athletic national team; Milan Milivojević (MM) – cyclist, member of Cycling club "Borac" Čačak (Serbia), and the member Serbian national team; Stefan Lopatić (SL) – ski biathlete, member SK "Romanija" Pale, and BIH national team. A total of 12 parameters were measured to assess the fitness profile (repetitive strength, explosive strength, speed and agility). The results recorded considerable homogeneity of the sample with mutual differences. In addition to mutual differences, all study participants are characterized by an extremely good fitness profile, as shown by the measurement results.

Keywords: fitness profile, abilities, detection, evaluation

[i] Correspondence: email pavlovicratko@yahoo.com

1. Introduction

1.1 Background: Runners (middle and long distance)

Anthropometric characteristics, Fitness profile and body composition are associated with running performance in middle and long-distance athletes [1,2]. The amount of subcutaneous adipose tissue of the lower extremities in men is directly related to the result of running 1500m and 10000m, enabling a much more efficient effect of the activity. According to Wan Nudri, Ismail, & Zawiak [3] physical ability and physique are important for success in athletic performance where a different type of body composition is usually required for maximum performance in certain athletic disciplines. Variables associated with racing disciplines include physical abilities, maximum oxygen consumption [4], body composition, [5], lactate threshold, and energy expenditure during running (running economy and stride length [6]. According to Pavlović, & Kozina [7] running on medium and long distances is a demanding athletic discipline which, in addition to good functional abilities, appropriate anthropometric characteristics, and adequate body composition, also implies an exceptional fitness profile of runners. Body size and strength contribute to motor performance, so an increase in strength is associated with an increase in total muscle mass [8]. A significant positive correlation between strength and performance suggests that stronger and more powerful individuals were athletes who also had more successful results [9]. However, the pattern of improving strength and physical ability is not uniform in all tasks, because strength may be important for the successful performance of some motor performances (throwing disciplines), but not so important for some others (long-distance racing disciplines). High-performance athletes require specific biological profiles with exceptional abilities and strong psychological characteristics.

1.2 Background: Cycling

Cycling, along with Nordic running and marathons, is one of the most demanding sports in terms of aerobic and fitness (motoric) abilities, and due to its prevalence around the world, it is considered a planetary sport. According to the rules of the World Cycling Federation (UCI), competitions are held on the road (Road cycling), on the track (Track), cyclo-cross competitions, mountain bike competitions (Mountain bike - MTB), bicycle moto-races (bicycle motocross "BMX") and cyclo-tourism competitions. Each of the disciplines uses a different type of bicycle and equipment for cyclists, which is adapted to specific conditions [10]. In the 250 km road stage, the plain and mountain terrain configurations are represented, so that most world-class cyclists participate in a combination of these different configurations and specialty. In today's conditions, world-class professional cyclists cover an average of 35,000 km to 45,000 km in one season [11,12,13], between 800 and 1,200 hours, while amateur national cyclists cover 15,000 to 18,000 km in the same period, between 350 and 500 hours. In professional cycling, 93min and 123min are spent in races on mostly flat terrain on mountain stages, which are at an intensity of 70% VO^2max. [14]. According to Knechtle, Rosemann, Wirth & Knechtle, [15]

anthropometric parameters correlate with race speed while training volume shows no significant correlation. Only a few anthropometric parameters have been shown to be useful for identifying talent and development programs in several sports [16]. Also, monitoring body composition (BC), and especially regional adiposity, can identify patterns associated with athletic performance and health [17]. Although BC can reflect many factors unrelated to physical activity and training, it is common knowledge that specific low or high adiposity itself can affect many different sports and cyclist performances [18]. Knowing the regional adiposity and profile of BC athletes can be very useful for coaches, for example, in improving development programs for their athletes and in longitudinal monitoring of changes in BC athletes, which may indicate athletic fitness [19]. Cycling training models are constantly evolving, and the results of top athletes are becoming more homogeneous, as shown by tables from the world cycling championships for professional cyclists in the disciplines: chronometer, cycle track (time trial) and mountain biking (MTB). In the process of many years of training, there are seasonal variations in relation to the type of training and competition preparation of cyclists. A very important control of the level of current training of athletes involves periodic testing using standardized procedures, where the method of laboratory testing provides the most reference data on the state of training of athletes - cyclists [20].

1.3 Background: Cross-country Skiing (Biathlon)

Cross-country skiing (biathlon) is an endurance sport. Individual races last 12 to 90 minutes for female athletes, and 22 to 140 minutes for men, involving downhill, uphill and level skiing [21]. In contrast to distance running and long-distance cycling, cross-country skiing uses both upper and lower body muscles [22]. An optimum sport-specific body size and body composition are required in order to maximize athletic performance, elite cross-country skiers are as lean as distance runners [23]. However, within the sport itself, variations in physiology have been noted as being attributed mainly to the body mass of the athletes, with the heavy skiers being faster in all types of terrain, except for the steep up hills, and the light skiers having an advantage on steep uphill courses. Cross-country skiing is a sport that requires endurance, as with cycling and running. Generally, in endurance sports, the higher the performance, the better the maximum oxygen intake. In cross-country skiing events, world-class athletes are reported to have higher maximum oxygen intake than national-level athletes [24, 25]. In addition, compared to national-level cross-country skiers, world-class cross-country skiers have superior anaerobic power, muscular endurance and muscle power, and high aerobic and endurance capabilities [26-29]. An important consideration in endurance training is the efficient distribution of exercise intensity, duration, and frequency [30-32]. In biathlon, sports mastery is highly dependent on sliding speed, and accurate and fast shooting [33-35]. High sports mastery is affected by athletic and technical fitness, functional capacity, age and years of sports experience [36].

Physical working capacity and body function indices of biathletes are related to the ratio of body mass and its components [36,37]. Body composition is the most

important anthropometry indicator in cross-country skiers. Male cross-country skiers have as their somatotype the ectomorphic mesomorph, while female skiers are of the endomorphic mesomorph type. Cross-country skiing is a sport discipline which focuses mostly on the pre-season "dry" preparatory training period. Training tools such as running, roller-skiing, cycling, swimming, canoeing, etc. are used for the development of endurance and strength performance. About 20% of the total volume of the training load is the training intensity which is called "the developing intensity". Today's athletes are adapting to this intensity in development.

The performance of all sportsmen (runner, cyclist, biathlete) is influenced by a number of factors (level of physical fitness, physiological and psychological abilities, technique, motor skills, body morphology, and application of biomechanical principles. The relationship of sports performance with physical readiness, and psychological and physiological abilities has been a problem for researchers for decades in order to develop an adequate physical and physiological profile of athletes, to be reliably used by different athletes to predict sports results [38]. The disciplines (runner middle distance, cycling, biathlon) include and provide an ideal situation for challenge, competition and testing of motor skills. It is motor fitness and its components that play an important role in various fields of sports activity, especially in runners, cyclists and biathletes. Fitness has a broader meaning that includes not only physical fitness, but also anatomical psychological and physical fitness, so fitness is not just a matter of muscle, but also physical capacity. Motor fitness (fitness) is considered the part of physical fitness that is responsible for any motor activity. There are various components of motor fitness such as strength, speed, endurance and agility and are considered conditional components of motor fitness [39].

Physical fitness is significant in all three sports disciplines (running, cycling, ski biathlon) and is an indispensable segment in the overall anthropological sports profile. According to our knowledge, there are no specific studies in Bosnia and Herzegovina (BIH) that analyze the differences in the fitness profile of runners, cyclists and biathletes. Precisely because of the lack of mentioned research, which is related to the fitness abilities of this sports population, the current study aims to detect and evaluate the fitness profile and the difference between these athletes.

2. Method and Material

2.1 The sample of participants

The study was conducted:

1. Uroš Gutić - runner middle and long distances, 23 years old (Body height 181cm; Body weight 67kg; BMI 20.02kg/m^2; Body fat 10,1%; Body muscle 60,4kg; Body water 64,1%; Heart pulse 41bmp; saturation O_2 98%), a member of AK "Sarajevo" and the BIH athletic national team.
2. Milan Milivojević – cyclist, 22 years old (Body height 185cm; Body weight 70kg; BMI 20,4kg/m^2; Body fat=10,6%; Body muscle 59,4kg; Body water 62,9%; Heart pulse

58bpm, saturation O_2 98%), a member of Cycling club "Borac" Čačak (Serbia), and the member Serbian national team.

3. Lopatić Stefan – biathlete, 28 years old (Body height 188cm; Body weight 87,8kg; BMI 24,8kg/m^2; Body fat17,2%; Body muscle 69,1kg; Body water 58,9%; Heart pulse 56bpm, saturation O_2 98%), a member SK "Romanija" Pale, and BIH national team.

2.2 The sample of variables

A total of 12 variables were variables of evaluation Physical fitness profile [40]

1) Push-ups (max. iter);
2) Sit-ups (max. iter.);
3) Pull-ups (max. iter.);
4) Speed 15m (sec.);
5) Speed 30m (sec.);
6) Speed 100m (sec.);
7) HGS $_{\text{Right hand}}$ (kg);
8) HGS $_{\text{Left hand}}$ (kg);
9) Speed of throwing a handball bal with 7m (m);
10) Throwing the ball (3kg) standing (m);
11) Throwing the ball (3kg) sitting (m);
12) Ilinois test agility (sec).

All three respondents have over 10 years of sports experience. The respondents voluntarily participated in the research.

2.3 Experimental design

Anthropometric measurements were performed according to the methodology of the International Society for the Assessment of Kinanthropometry (ISAK). The standard metric instruments were applied: Stadiometer used for measuring body height (SECA 206, Germany); Body weight and Body Composition were assessed with the Bioelectrical Impedance Analysis (BIA) method using a body composition analysis (Tanita InnerScan BC-545N, Tokyo, Japan), in accordance with the measurement protocol. Their HGS of them was measured by the method of isometric dynamometry (digital dynamometer CAMRY EH101, USA). The results are expressed in kilograms (kg) with a measurement accuracy of 0.01 kg. To estimate arm speed the subject threw the handball ball from a distance of 7m with the dominant right hand. The speed of movement of the ball was measured by the Velocity Speed Radar Gun-Bushnell (model 101911, USA). All measurements were in accordance with the procedures of the Declaration of Helsinki.

3. Result and Discussion

Running on medium and long distances, cycling and cross-country skiing (biathlon) belong to endurance disciplines with similar requirements, the morphological and functional structure of competitors, as well as muscle structure. These disciplines are

mainly based on aerobic potential, where morphological structure and physical profiles play an important role [7]. The current study aims to detect and evaluate the fitness profile and differences between endurance sportsmen (runner, cyclist, biathlete). To assess the fitness profile (motor skills) of the sample, a total of 12 tests were used to detect the degree of physical fitness (Figure 1). The results are presented graphically so that quantitative mutual numerical differences between the tested subjects can be established. The defined sample of respondents (in the chapter method and material) records minor differences in body composition. The body mass of the participants is almost the same for cyclist and runner (70kg vs 70.7kg) compared to biathlete (87.8kg). As a consequence of body mass and height, BMI biathlon (SL-24.8kg/m²) increased compared to runner (UG-21.6kg/m²) and cycling (MM-20.4kg/m²). The percentage of fat in the body of runners and cyclists is extremely low (10.1% vs. 10.6) compared to biathletes (17.2%), which is expected because they are top-quality athletes. Fat is inversely related to the percentage of water in the muscles in all participants. The highest percentage of water is present in runner UG (64.1%), MM (62.9%), SL (58.9%). Muscle mass is dominant in biathletes (69.1kg), which makes up 79% of the total body mass, it is significantly lower in runners (60.4kg) or 85% of the total body mass and cyclists (59.4kg) or 85% of the total mass.

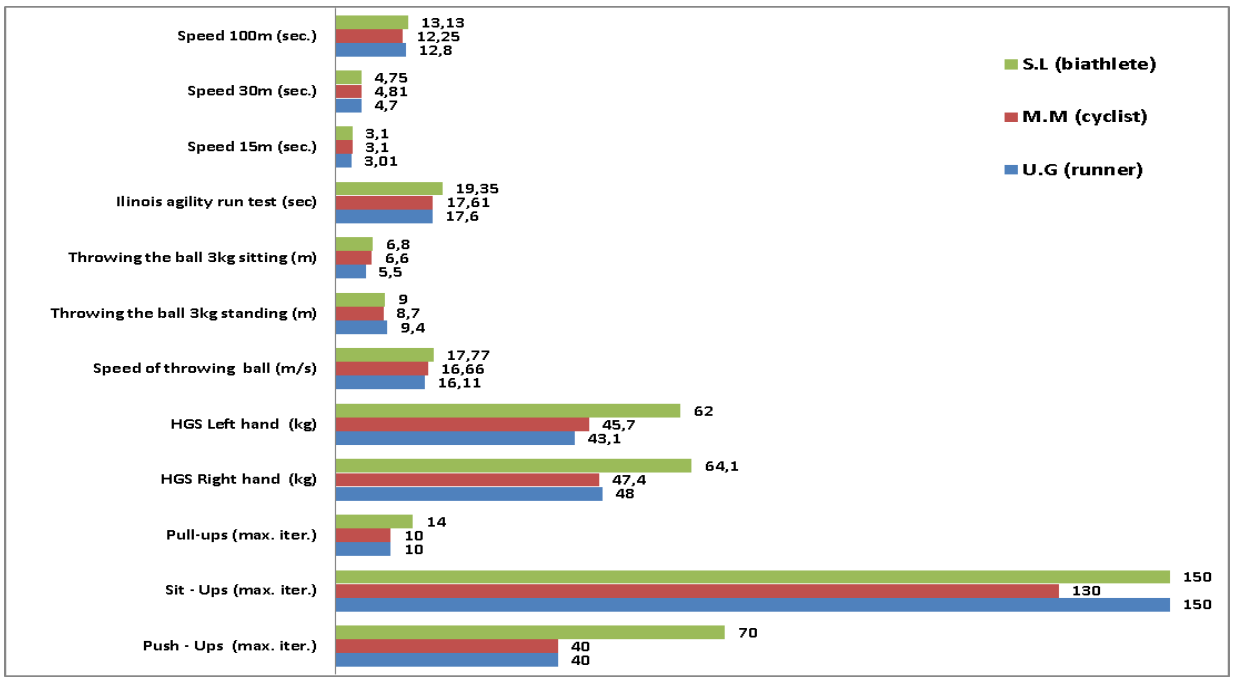

Figure 1: Fitness profile of sportsmen: runner (U.G), cyclist (M.M), biathlete (S.L)

The results contained (Figure 1) define the fitness profile of the measured athletes of three different sports disciplines with considerable homogeneity in the individual measured tests. Repetitive power assessed with three tests (Push-ups max., Sit-ups max., Pull-ups max.) records the best results of biathlete S.L (Push-ups max.=70 iter., Sit-ups max.=150 iter., Pull-ups max. ups max.=14 iter.), while the runner U.G and the cyclist M.M have the same test result (Push-ups max=40 iter.).

The fitness test (Sit-ups max.) gives an advantage to the runner U.G (150 iter.) compared to the cyclist M.M (130 iter.). The dynamometry also shows a better result of the biathlete (S.L) than the runner (U.G) and the cyclist (M.M), by an average of about 16 kg. The hand grip strength of runners and cyclists for both hands is relatively uniform. In the evaluation of the explosive strength of the caudal extremities (throwing a ball 3 kg) while standing, the runner (9.4m) achieved the highest shot, then the biathlete (9m) and the cyclist (8.7m) achieved the highest shot. In the same test of explosive power, the sitting throw, the inverse of the ranking is obtained. The most successful shot was made by a biathlete S.L (6.8m), followed by a cyclist (6.6m) and the highest shot was recorded by a runner (5.5m).

The speed of the caudal limbs was assessed by a motor test by throwing a handball at a distance of 7m. The highest handball throwing speed was achieved by the biathlete (17.77m/s), which is a slightly better result compared to the cyclist (16.66m/s) and the runner (16.11m/s). Runner U.G had the best result in sprint speed and explosive power (15m, 30m) with 3.01 sec., i.e. 4.70 sec. while in the 100m the cyclist (M.M) was the fastest (12.25sec.).

The anthropometric characteristics of our sample are determinants of the performance of top athletes, and together with body structure, affect physical performance. Somatotype and individual anthropometric characteristics differ depending on the athlete's specialization, and sports discipline. It is well known that specific low or high adiposity in itself can affect many different sports and the performance of runners, cyclists or biathletes [18]. Determination of body composition, especially concerning body fat, total body water and according to up-to-date research, even intracellular and extracellular water, and the amount of oxygen processed by muscle cells is an important part of most of the evaluation of so-called health fitness on the one hand, and the assessment of nutrition and an individual’s state of health on the other hand [7]. Based on these parameters, our pattern has good fitness with smaller fat differences and slightly higher differences in the participation of water in the body. Mostly, physical characteristics and body composition are important for excellence in athletic performance, where most often certain disciplines require a different type of structure and body mass for maximum performance [5]. Our results correspond to the findings of the study [18,41], which are based on the fact that body morphology together with body composition is important in the physical performance of sports endurance, which adapts to one of the three known somatotypes (endomorph, mesomorph, ectomorph). Energy power and economy of work are the main performance parameters of runners, cyclists and ski biathletes. The first parameter is directly correlated with the athlete's physiological profile, while the economy of work defines the efficiency in moving the body in space and is directly related to the athlete's motor and biomechanical profile [7]. Specific components of fitness (agility, balance, coordination, strength, reaction time and speed) must be integrated in the best possible way, which is confirmed by the results of this study. In the current study, the values of the basic motor components of the cyclist, runner and biathlete are estimated, which are of great importance for the

success of the sportsmen. Findings by authors [42, 43] suggest evidence that muscle mass, maximal muscle strength, and isokinetic muscle function are important predictors of performance in these disciplines. These sports (runners, cycling, biathletes) define the cyclical activity of medium and high intensity, where, in addition to good functional abilities, and adequate morphological and physical status, they also imply a good state of development of motor (fitness) abilities of the athletes, which can be concluded from the obtained results of current fitness testing. Homogeneity is especially present in some tests between runners (U.G) and cyclists (M.M).

Some research has proven that the competitive activity of runners, cyclists and ski biathletes places high demands and levels on their physical abilities [44, 45]. The training process is mainly based on the development of physical qualities, among which the most important are different types of endurance, and motor skills depending on the nature of the sport. Also, the development of these abilities is possible only in the case of a targeted impact on their physiological systems, especially the energy supply mechanisms for muscle motor activity [46]. These cyclical activities are linked by muscle kinetic chains, enabling good posture and activity of the trunk posture, with the engagement of the abdominal muscles, pelvic muscles and the muscles of the caudal extremities. In our study, the strength of the muscle chains of the runners' arms and shoulder girdle was assessed by the maximum number of push-ups, trunk lifts, and the number of pull-ups, which are indicators of the good motor status of the study participants. The hand grip strength of the sample assessed by dynamometry is in average values in relation to table values [42]. The state of explosiveness and the speed of individual movement of the cranial extremities were assessed by throwing a ball (3kg) from a standing and sitting position and are quite good, considering the body mass of our sample. The obtained results of the current measurement of our sample support the results of previous studies [47, 48]. Given the fact that the speed of running medium and long distances, cycling and ski biathlon is in certain parts of a sprinting character, at the start of the race, while overtaking the opponent, during the finish, etc. sprinting speed is extremely important, which is confirmed by the results of running 15m, 30m, 100m. (Figure 1) which mobilizes glycolytic mechanisms. The Ilinois agility test is an indicator that our athletes have a well-developed so-called motor intelligence (agility), which largely depends on the degree of development of the central nervous system [7].

The obtained results of our studies show that size, physical status, and body strength contribute to motor performance, that is, an increase in total muscle mass and realization of motor movements, which is in accordance with research [8,26-29]. Also, differences in the fitness profile of our sample are evident, but with smaller numerical values, especially in the runner-cyclist relationship.

4. Conclusion

The aim of the current study was to detect and evaluate fitness profiles and differences between athletes in endurance sports (running, cycling, biathlon). To assess the fitness

profile, a total of 12 tests were used to detect the degree of physical fitness. The results recorded mutual differences between biathletes versus runners and cyclists in terms of morphology, body composition, and fitness profile. A cyclist and a runner have almost identical morphological profiles, physique and fitness profiles. Motoric (fitness) profile, along with functional abilities, is very important in these sports for achieving top results.

Conflict of interest statement
The authors declare that they have no conflicts of interest.

Acknowledgements
We would like to thank the participants of this study, Uroš Gutić, Milan Milivojević and Stefan Lopatić for their time and voluntary participation during the measurements.

About the Authors
Ratko Pavlović is a Professor of Sports and Rehabilitation Sciences of University of East Sarajevo, Faculty of Physical Education and Sport. His current research interests are track and field, kinanthropometry, sports science, isokinetic, biomechanics of sport.
Email: pavlovicratko@yahoo.com;
ResearchGate: https://www.researchgate.net/profile/Ratko-Pavlovic-2.
Mensur Vrcić is Full Professor at Faculty of Sport and Physical Education, University of Sarajevo. Areas of research include athletic throwing, sports recreation and fitness programs.
Email: mvrcic41@gmail.com;
ResearchGate: https://www.researchgate.net/profile/Mensur-Vrcic.
Nikola Radulović is Teaching Assistant, University of Novi Sad, Faculty of Sport and Physical Education. She is researching in the field of sport science, track and field, kinesiology.
Email: nikolaradulovicfsfv@gmail.com;
ResearchGate: https://www.researchgate.net/profile/Nikola-Radulovic-3.

References

1) Arrese AL, & Ostáriz ES. (2006). Skinfold thicknesses associated with distance running performance in highly trained runners. Journal of Sports Sciences, 24 (1), 69-76. doi: 10.1080/02640410500127751.
2) Knechtle B, Knechtle P, Schulze I, & Kohler G. (2008). Upper arm circumference is associated with race performance in ultra-endurance runners. British Journal of Sports Medicine, 42(4), 295-299. doi: 10.1136/bjsm.2007.038570.
3) Wan Nudri WD, Ismail MN, & Zawiak H. (1996). Anthropometric measurements and body composition of selected national athletes. Malays J Nutr, 2(2), 138-147.

4) Maldonado-Martin S, Mujika I, & Padilla S. (2004). Physiological variables to use in the gender comparison in highly trained runners. J. Sports Med. Phys. Fit. 44 (1), 8–14.
5) Brandon L.J, & Boileau RA. (1992). Influence of metabolic, mechanical and physique variables on middle distance running. The journal of sports medicine and physical fitness, 32(1), 1-9.
6) Maldonado S, Mujika I, & Padilla S. (2002). Influence of body mass and height on the energy cost of running in highly trained middle- and long-distance runners. Int J Sports Med.23 (4), 268- 272. doi: 10.1055/s-2002-29083
7) Pavlović, R., Kozina, Z. (2022). Differences in anthropometric characteristics and body composition of athletes in cyclic endurance-type activities: a case study. Journal of Advances in Sports and Physical Education. 5 (10), 225-234. 10.36348/jaspe.2022.v05i10.00X
8) Lucia A, Esteve-Lanao J, Oliván J, Gomez-Gallego F, San Juan, A. F., ... & Foster, C. (2006). Physiological characteristics of the best Eritrean runners—exceptional running economy. Applied physiology, nutrition, and metabolism, 31(5), 530-540. doi: 10.1139/h06-029.
9) Ball TE, Massey BH, Misner JE, Mckeown BC & Lohman TG. (1992). The relative contribution of strength and physique to running and jumping performance of boys 7-11. The Journal of sports medicine and physical fitness, 32(4), 364-371.
10) Pavlović R, Milivojević M, Gerdijan N. (2022). Anthropometric Characteristics, Body Composition and Fitness Profile of Serbian Cyclist Milan Milivojević: Case Study. European Journal of Physical Education and Sport Science. 7 (6), 83-101.doi./10.46827/ejpe.v7i6.4139.
11) Coyle EF, Feltner ME, Kautz SA, Hamilton MT, Montain SJ, et al. (1991). Physiological and biomechanical factors associated with elite endurance cycling performance. Medicine and science in sports and exercise. 23(1), 93-107.
12) Mujika I, & Padilla S. (2001). Physiological and performance characteristics of male professional road cyclists. Sports medicine, 31 (7), 479-487. doi: 10.2165/00007256-200131070-00003.
13) Lucia A, Hoyos J. & Chicharro JL. (2003). In High-Tech Cycling, Vol. Second (Ed., Burke, E.) Human Kinetics, Champaign, 265-288.
14) Lucia A, Hoyos J, & Chicharro JL. (2001). Physiology of professional road cycling. Sports Medicine, 31(5), 325-337. Doi: 10.2165/00007256-200131050-00004.
15) Knechtle B, Rosemann T, Wirth A, & Knechtle P. (2009). Moderate Association of Anthropometry, But Not Training Volume, With Race Performance in Male Ultraendurance Cyclists. Research Quarterly for Exercise and Sport. 80 (3), 563-568. doi: 10.1080/02701367.2009.10599594.
16) Brunkhorst L. & Kielstein H. (2013). Comparison of anthropometric characteristics between professional triathletes and cyclists. Biol. Sport.30,(4), 269-273. doi: 10.5604/20831862.1077552.

17) Ackland TR, Lohman TG, Sundgot-Borgen, J....et al. (2012). Current status of body composition assessment in sport: Review and position statement on behalf of the Ad Hoc research working group on body composition health and performance, under the auspices of the I.O.C. medical commission. Sport. Med. 42, 227–249. doi: 10.2165/11597140-000000000-00000.
18) Alvero-Cruz JR, García Romero JC, Ordonez FJ, Mongin D, Correas-Gómez L, Nikolaidis PT, & Knechtle B. (2022). Age and Training-Related Changes on Body Composition and Fitness in Male Amateur Cyclists. International Journal of Environmental Research and Public Health. 19(1), 93. https://doi.org/10.3390/ijerph19010093
19) Legaz A. (2005). Changes in performance, skinfold thickneses, and fat patterning after three years of intense athletic conditioning in high-level runners. Br. J. Sports Med. 39 (11), 851–856. doi: 10.1136/bjsm.2005.018960.
20) Peiffer JJ, Abbiss CR, Chapman D, Laursen PB, & Parker DL. (2008). Physiological characteristics of master-level cyclists. J Strength Cond Res. 22(5), 1434-1440. doi: 10.1519/JSC.0b013e318181a0d2.
21) Ekblom B, & Bergh U. (2000). Cross-country skiing. In Maughan RJ (ed). Nutrition in Sport. Oxford: Blackwell Science. pp: 656-62.
22) Mahood NV, Kenefick RW, Kertzer R, Quinn TJ. (2001). Physiological determinants of cross-country ski racing performance. Med Sci Sports Exerc. 33 (8):1379-84. doi: 10.1097/00005768-200108000-00020
23) Sandbakk Ø, Holmberg HCA (2014). A reappraisal of success factors for Olympic cross-country skiing. Int. J. Sports Physiol. Perform. 9 (1), 117–121. doi: 10.1123/ijspp.2013-0373
24) Holmberg HC, Rosdahl H, Svedenhag J. (2007). Lung function, arterial saturation and oxygen uptake in elite cross country skiers: Influence of exercise mode. Scand. J. Med. Sci. Sports., 17 (4), 437–444. doi: 10.1111/j.1600-0838.2006.00592.x.
25) Sandbakk Ø, Holmberg HC, Leirdal S, Ettema G. (2011). The physiology of world-class sprint skiers. Scand. J. Med. Sci. Sports., 21, e9–e16.
26) Staib JL, Im J, Caldwell Z, Rundell KW. (2000). Cross-country ski racing performance predicted by aerobic and anaerobic double poling power. J. Strength Cond. Res. 14, 282–288.
27) McGawley K, Holmberg HC. (2014). Aerobic and anaerobic contributions to energy production among junior male and female cross-country skiers during diagonal skiing. Int. J. Sports Physiol. Perform., 9 (1), 32–40. doi: 10.1123/ijspp.2013-0239.
28) Akay MF, About F, Özçiloglu M, Heil D. (2016). Identifying the discriminative predictors of upper body power of cross-country skiers using support vector machines combined with feature selection. Neural Comput. Appl. 27, 1785–1796.
29) Danielsen J, Sandbakk Ø, McGhie D, Ettema G. (2018). The effect of exercise intensity on joint power and dynamics in ergometer double-poling performed by cross-country skiers. Hum. Mov. Sci., 57, 83–93. doi: 10.1016/j.humov.2017.11.010.

30) Aagaard P, Andersen JL. (2010). Effects of strength training on endurance capacity in top-level endurance athletes. Scand. J. Med. Sci. Sports. 20 Suppl.2, 20, 39–47. doi: 10.1111/j.1600-0838.2010.01197.x.
31) Sandbakk Ø, Hegge AM, Losnegard T, Skattebo Ø, Tønnessen E, Holmberg HC. (2016). The physiological capacity of the world's highest-ranked female cross-country skiers. Med. Sci. Sports Exerc. 48 (6), 1091–1100. doi: 10.1249/MSS.0000000000000862.
32) Kim TH, Han JK, Lee JY, Choi YC. (2021). The Effect of Polarized Training on the Athletic Performance of Male and Female Cross-Country Skiers during the General Preparation Period. Health care., 9, 851. https://doi.org/10.3390/
33) Cholewa J, Gerasimuk D, Szepelawy M. & Zajac A. (2005). Analysis of the structure of the biathlon runs. Acta Universitatis Palackianae Olomucensis. Gymnica, 35 (1), 35-42.
34) Carlson R. (2011). Talent detection and competitive progress in biathlon – a national example. Polish Journal of Sport and Tourism, 18 (4), 290-295.
35) Kočergina N, Čepulėnas A. (2012). Indices Of Elite Female Biathletes' Age and Body Composition. Lase Journal of Sport Science. 3 (2), 69-78
36) Psotta R, Sviráková D, Bunc V, Šeflová I, Hrásky P. & Martin J. (2009). Aerobic fitness, running performance and body composition of Czech elite male summer biathletes. Fitness Society of India, 5 (1), 41-49.
37) Bunc V, Vávra V & Levora P. (2005). Body composition and selected maximal functional performance in top young biathletes. In: Müller, E., Bacharach, D., Klika, R., Lindinger, S., Schwameder, H. (Eds.). Science and Skiing III (pp. 300-307). Adelaide, Oxford, New York: Meyer and Meyer
38) Ortega FB, Ruiz JR, Castillo MJ., Sjostorm M (2008). Physical fitness in childhood and Adolescence: A Powerfull Marker of Health. International Journal of Obesity. 32(1), 1-11. doi: 10.1038/sj.ijo.0803774
39) Arafat, Y., Rickta, JF, Mukta, FTJ. (2020). A comparative study of motor fitness between a sprinter and long-distance runner in Bangladesh. International Journal of Yoga, Physiotherapy and Physical Education. 5 (3), 18-22
40) Mackenzie, B (2005) 101 Performance Evaluation Tests. Published by: Electric Word plc 67-71 Goswell Road London. https://www.brianmac.co.uk/eval.htm).
41) Gabbett T, & Georgieff B. (2007). Physiological and anthropometric characteristics of Australian junior national, state, and novice volleyball players. The Journal of Strength & Conditioning Research, 21(3), 902-908. doi: 10.1519/R-20616.1.
42) Sunde, A., Storen, O., Bjerkaas, M., Larsen, M. H., Hoff, J. & Helgerud, J. (2010). Maximal strength training improves cycling economy in competitive cyclists. Journal od Strengh and Conditioning Researcg, 24(8), 2157-2165. doi: 10.1519/JSC.0b013e3181aeb16a.
43) Park JH, Kim JE, Yoo JI, Kim YP, Kim EH, & Seo TB. (2019). Comparison of maximum muscle strength and isokinetic knee and core muscle functions

according to pedaling power difference of racing cyclist candidates. J Exerc Rehabil.15(3), 401-406. doi: 10.12965/jer.1938180.090.

44) Bakaev, V.V., Bolotin, A.E.,Vasil'eva, V.S. (2015). Factors determining sports specialization of cross country skiers. Teoriya i Praktika Fizicheskoy Kultury, (2), 40-41.
45) Kuznetsova Z., Kuznetsov A., Mutaeva I., Khalikov G. and Zakharova A. (2015). Athletes Preparation based on a Complex Assessment of Functional State. In Proceedings of the 3rd International Congress on Sport Sciences Research and Technology Support, pp. 156- 160.
46) Ammann R. and Wyss T. (2015). Running Asymmetries during a 5-Km Time Trial and their Changes over Time. In Proceedings of the 3rd International Congress on Sport Sciences Research and Technology Support, pp.161-164.
47) Hansen EA, Raastad T, & Hallén J. (2007). Strength training reduces freely chosen pedal rate during submaximal cycling. Eur J Appl Physiol. 101 (4), 419–426. doi: 10.1007/s00421-007-0515-7
48) Hodges PW. (2003). Core stability exercise in chronic low back pain. Orthop Clin North Am. 34 (2), 245–254. doi: 10.1016/s0030-5898(03)00003-8.