ISSN 2664-9837

PEDAGOGY of Physical Culture and Sports

№02/2022

Pedagogy of Physical Culture and Sports

2022
02

Key title: Pedagogy of Physical Culture and Sports (Abbreviated key-title: Pedagogy phys. cult. sports; ISSN 2664-9837).

Founders: Iermakov Sergii Sidorovich (Ukraine); (doctor of pedagogical sciences, professor).

Certificate to registration: KB 24393-14233ПР 13.03.2020.

Previous title «Pedagogics, psychology, medical-biological problems of physical training and sports» (e-ISSN 2308-7269; p-ISSN 1818-9172; ISSN-L 2308-7269).

Frequency – 6 numbers in a year.

Address of editorial office:

Box 11135, Kharkov-68, 61068, Ukraine,

Tel. 38 099 430 69 22

e-mail: sportart@gmail.com

https://www.sportpedagogy.org.ua

INDEXING

Web of Science Core Collection - [Emerging Sources Citation Index (ESCI)] - http://mjl.clarivate.com/cgi-bin/jrnlst/jlresults.cgi?PC=MASTER&ISSN=*2664-9837

Scopus - https://www.scopus.com/sourceid/21101040604

DOAJ (Directory of Open Access Journals) - https://doaj.org/toc/2664-9837

ERIH PLUS (The European Reference Index for the Humanities and the Social Sciences) - https://dbh.nsd.uib.no/publiseringskanaler/erihplus/periodical/info?id=497967

WorldCat (WorldCat is the world's largest network of library content and services) – http://www.worldcat.org

Scilit (A database of scientific & scholarly literature) – https://www.scilit.net/journal/4323609

OpenAIRE - https://www.openarchives.org/Register/BrowseSites?viewRecord=https://sportpedagogy.org.ua/index.php/ppcs/oai

PBN (Polish Scholarly Bibliography) - https://pbn.nauka.gov.pl/core/#/journal/view/5edbed29ad49b31d36de4021/current

V.I.Vernadskiy National Library of Ukraine - http://nbuv.gov.ua

Google Scholar – https://scholar.google.com/citations?user=RoS9xrUAAAAJ&hl=en

Dimensions - https://app.dimensions.ai/discover/publication?search_text=10.15561%2F26649837.&search_type=kws&search_field=doi

Crossref - https://search.crossref.org/?q=2664-9837

Open Ukrainian Citation Index (OUCI) - https://ouci.dntb.gov.ua/en/editions/E1DygdjZ/

MIAR - http://miar.ub.edu/issn/2664-9837

ResearchGate - https://www.researchgate.net/journal/2664-9837_Pedagogy_of_Physical_Culture_and_Sports

Hinari Access to Research for Health - http://extranet.who.int/hinari/en/journal_keyword_search.php?query=Pedagogy+of+Physical+Culture+and+Sports

PKP index - http://index.pkp.sfu.ca/index.php/browse/index/9245

Sherpa Romeo - https://v2.sherpa.ac.uk/id/publication/40500

EDITORIAL BOARD

CONTENTS

Investigation of the effect of isometric core strength training in addition to basic basketball trainings on explosive power in children aged 9-17

Nurkan Yılmaz[ABCDE]

Department of Physical Education and Sports Teaching, Faculty of Sport Sciences, Inonu University, Turkey

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Background and Study Aim With its dynamic and constantly changing characteristics, basketball, which requires more than one movement, is one of the most preferred and popular team sports in the world. It is important to know that basketball requires programs based on speed, agility and strength fitness components, in which endurance and strength parameters are predominant. In this context, resistance training, which provides skill excellence and increased muscle strength, is important for basketball players. The aim of this study is to examine the effects of 4-week specific core training applied to pre-adolescent and adolescent children who do basic basketball training on explosive strength.

Material and Methods A total of 16 [Control Group (CG): n=8; Experimental Group (EG): n=8] individuals (age 13.29 ± 1.96 years) who did not have any health problems from basketball school and continued basketball basic training were included in the study. The groups continued their usual basketball basic training program (2 days a week, 60 minutes a day). However, in addition to the basic training program, the experimental group was subjected to an isometric training program for 12-minute core strengthening. Training programs were made for a total of 4 weeks. We examined the effects of core training on speed, vertical jump and agility parameters. Statistical analyzes of the data obtained as a result of the research were obtained using the IBM SPSS 23.0 package program.

Results There was no difference between the groups for sprint and vertical jump parameters of core and basic basketball training ($p>0.05$). However, there was a significant difference in favor of EG in the agility test analysis results ($p<0.05$). As a result, we can say that 4-week core training applied in addition to the basic basketball training program in children improves agility characteristics.

Conclusions The findings showed that core training programs have positive effects on explosive strength parameters. In addition, strengthening the core area significantly improved the agility parameter, which is important in ground-direction changes. This, in parallel with the studies, supported that core training programs should be an integral part of other training programs. This study also showed that core stabilization training applied in a short time improves explosive strength parameters in children.

Keywords: basketball, core strength, children, biomotoric parameters.

Introduction

Basketball is one of the most popular team sports that has been accepted worldwide and is the most preferred [1, 2]. The basketball game, which offers different challenges in many time periods with its dynamic and constantly changing characteristics, is a sports activity that requires more than one movement [3, 4]. Considering the movements it contains due to its physical and physiological performance characteristics, it is a high-intensity and short-term anaerobic exercise that includes different sprint types, sudden accelerations/decelerations, jumps, flexibility, jumps, agility, upper and lower body strength or in low/moderate intensity and partially prolonged aerobic exercise activities such as standing and walking [2, 5, 6, 7, 8]. In addition to all these motoric skills, it is important to be able to dribble by filling positions, to be able to perform a good defense against the opponent and to apply technical and tactical elements in the best way in basketball, which includes many difficulties in a small area and requires more precision [4, 8].

The main factor for success for every sport branch is to develop good conditioning programs based on the specific physiological demands of that branch [9]. In this context, it is important to know that basketball specifically requires programs that focus on maximum aerobic/anaerobic endurance and power parameters on the basis of speed, agility and power fitness components [4, 6, 10]. In order to obtain the best efficiency for basketball, as a synthesis of all the above-mentioned features: morphological body type, genetic structure, functional and motor abilities, specific technical and tactical abilities, psychological and sociological characteristics constitute the complex skills of a basketball player [4]. Therefore, in basketball, where many player groups start at the age of 5-6, it is important that the age to start training is 7-8 in order to perform these skills in the best way [1, 4]. Because in studies, it has been stated that pre-adolescent and adolescent

doi:10.15561/26649837.2022.0201

athletes or non-athletes have increased muscle strength, aerobic and anaerobic power, jumping ability and muscular endurance with short-term training [11]. In studies supporting these increases, they stated that coordination abilities improve with age and sports expertise, for example, adolescent basketball players exhibit much better vertical jump, complicated reaction, focused attention and speed of movement compared to their non-sport peers. Therefore, it is predicted that there will be a strong relationship between coordination and specific conditioning in all age groups of basketball players [10]. For example, it has been stated that male basketball players with higher skill levels have higher vertical jump, faster and more agility values than less talented players [2].

Especially resistance training, which is done in the early stages of life, prepares the necessary infrastructure for higher-level training to be done in the later periods, by increasing skill perfection and muscle strength. In recent years, research on the effects of strength exercises performed with appropriate techniques and continuous supervision on children and adolescents. It is known that strength training increases many biomotor abilities and performance by increasing muscle strength in pre-adolescent and adolescence periods. On the other hand, with the advancing time, the importance of individualization of programs is an undeniable fact due to innate genetic differences between individuals, differences in strength or/ and strength training and general fitness [12, 13, 14]. In the game of basketball, which is played at adolescent ages, which requires technical and physical ability and versatility, especially the players have a high rate of possession of the ball in the small playground. It requires many movements that include explosiveness in more than one direction, including acceleration, deceleration and jumping in various play styles. For this reason, it has been stated that power is important for changing direction performance in adolescent basketball players in various planes of motion [15].

Resistance training is important for basketball players. With the power obtained from basketball-specific resistance training programs, it causes changes in skeletal muscle, central and peripheral nervous system resulting in increased muscle strength output. Thus, athletes will be motivated to handle the high-stress workload that may occur during training or play more easily. On the other hand, strength training programs are important to prevent injuries that may occur with adequate strength, rehabilitate injuries and/or improve long-term health [3, 14]. Sports medicine specialists emphasized the importance of core strengthening techniques, which have become a fitness trend in the sports medicine world in recent years, in order to increase performance and prevent injury, and emphasized core strengthening, which is often called lumbar stabilization. The core can be described as a muscular box with the abdominals anteriorly, the paraspinals and gluteals posteriorly, the diaphragm as the roof, and the pelvic floor and hip girdle muscles [16, 17]. Core muscles, on the other hand, are defined as a structure that connects the lower extremities, pelvis, spinal cord, ribs and upper extremities with a kinetic chain [18]. It is advocated as an important prerequisite to prevent low back pain, increase athletic performance and protect musculoskeletal health, especially in performing some daily activities such as walking, climbing stairs, standing upright, as well as the implementation of many other sports such as trunk and core muscle development, football, basketball, athletics, and jumping disciplines [19, 20]. Athletes need sufficient balance, strong core stability and neuromuscular control to effectively perform the movements required by their sports [21]. Because the movements starting from the core muscle system always keep our kinetic response and readiness against the opponent alive in providing motor control, standing against gravity or torques [18].

It is stated that regularly followed and well-planned core training programs that emphasize the strengthening of the core region (for example, focusing on the abdominal, waist, trunk and hip muscles) are also suitable for children. In addition, it can be said that it provides postural benefit in gaining sports-specific skills and stabilizing the lumbosacral region, as well as the ability to perform challenging physical tasks that require core muscle strength, good condition and control [14, 18, 22]. In a study on the subject, it was seen that the 8-week core stability training program developed functional movement models and dynamic postural control in athletes, and it was more beneficial especially in athletes with weak movement skills [21]. From this point of view, the aim of our study is to examine the effects of specific core training applied to pre-adolescent and adolescent children who do basic basketball training in basketball school on explosive strength.

Material and Methods

Participants

A total of 16 [Control Group (CG), n=8; Experimental Group (EG), n=8] individuals (age 13.29 ± 1.96 years) who did not have any health problems from basketball school and continued basketball basic training were included in the study. If they had a history of health problems, a disease or physical condition that could affect physical activity, they were excluded from the study. All of the participants were previously informed about the testing procedures and any known risks, and provided their own written informed consent. Participants were asked not to do any exercise 24 hours before the tests. All of the procedures were in accordance with the Helsinki Declaration of 2021. This study was approved by University of Inonu Ethics Committee for research on human participants.

Research Design

Individuals who regularly attend basketball school 2 days a week for 1 hour a day for basic basketball training were included in the study. Individuals were divided into two groups as CG and EG. The groups continued their usual basketball basic training program (2 days a week, 60 minutes a day) (table 1). However, in addition to the basic training program, the experimental group was subjected to an isometric training program for 12-minute core strengthening (table 2). After obtaining the demographic and biometric information of the individuals, the first performance tests (sprint, jump and agility) were measured before the training programming. After the measurements, the individuals started to work in order to apply the training protocol created specifically for the groups for a total of 4 weeks. After the training program was over, the tests applied before the training were also applied after the training. All tests were administered in the indoor gym of the basketball school. All the data obtained were recorded on the form created specifically for the study.

Height and Body Mass

All measurement procedures were performed without minimal clothing and shoes. The height measurements of the participants were measured with a 0.1 cm precision portable stadiometer (Seca Ltd., Bonn, Germany) with the head in the frankfort plane, while the body was upright and the weight was evenly distributed on both legs. Body weight (VA) and body fat ratio measurements were measured with a body analyzer with a capacity of 270 kg and a sensitivity of 100 g (Tanita SC-330S, Amsterdam, Netherlands).

Height and Body Mass

All measurement procedures were performed without minimal clothing and shoes. The height measurements of the participants were measured with a 0.1 cm precision portable stadiometer (Seca Ltd., Bonn, Germany) with the head in the frankfort plane, while the body was upright and the weight was evenly distributed on both legs. Body weight (VA) and body fat ratio measurements were measured with a body analyzer with a capacity of 270 kg and a sensitivity of 100 g (Tanita SC-330S, Amsterdam, Netherlands).

In addition to the regular basketball basic training program, the participants were included in the basic core strength training program. The core stability program was created from 4 different isometric positions, each lasting 30 seconds and performed in two repetitions.

Participants were required to maintain a static position with only their forearms and toes touching the ground. Subjects were asked to maintain hand-eye contact, a neutral spine, and a straight line from head to ankles. The coach demonstrated each of the 4 exercises with their proper techniques. Afterwards, the participants were given a trial for 5 seconds. The test started when the participant showed the correct position. Individuals were asked to keep the exercise as long as possible for the specified time. However, if they could not hold the position for the specified time, they were instructed to fall to the ground and then return to the exercise within 1-2 seconds. Rest periods of 30 seconds between repetitions and 120 seconds between each plank exercise were given [23, 24, 25].

Test Protocols

Sprint Test

The 20 m sprint run was measured in an indoor

Table 1. Basketball basic training protocol

Groups	Weeks	Days	Tımes	Content of the training
				Basketball specific warm-up
Control				Basic Ball handling skills
	4	2	60 min.	Simple fundamental movement training
Experimental				Motoric feature development studies
				Stretch and cool down

Table 2. The EG core stability protocol

Group	Weeks	Days	Times	Content of the training
Experimental	4	2	12 min.	Plank (prone, supine, right and left side) 30 sec. x 2 rep.

environment using an infrared photocell device (Sport Expert, Tümer Engineering / Turkey), a two-door timing system placed at the start and finish lines. Subjects stood ready in a semi-crouched position with the tips of their toes 50 cm away from the starting line after they had done adequate warm-ups before the measurement. When they felt ready, they were asked to run at the maximum speed they could run. Each individual was given two attempts with a recovery period of approximately 3 minutes between them. Individuals were verbally motivated throughout all trials to achieve the best outcome. At the end of the run, the duration of the distance covered was recorded in 's' with an electronic stopwatch connected to the photocell mechanism. The best time obtained was used for analysis. Also, enough space was left for all participants to slow down after the run [10, 26, 27, 28, 29].

Vertical Jump

The vertical jump test is a standardized test for measuring explosive power, vertical jump and athletic performance. The vertical jump height indicator (Vertec/by Jump USA) was used for the measurement of this test. At the moment preceding the jump, the participants could freely flex the hip, knee, and ankle joints and prepare the upper limbs for a sudden upward thrust, in an effort to promote the highest vertical jump possible. The participants stands with feet apart below the height indicator. The feet are at shoulder-width. The participants swings his arms forward and up, jumps upward and tries to make contact with the rod of the indicator with his right hand at the position which indicates the highest possible value, lands in the starting position and repeats the jump, only now trying to make contact with the rod of the indicator using his left hand. The rest time between jumps was 20 s. The participant's vertical jump height was calculated as the difference between their maximum jump height and standing reach height. "Peak Power" was calculated from the maximal jump height of three trials [30, 31].

Modified T Agility Test

The modified agility t-test is a recently established contemporary protocol as a measure of defensive movements and speed in changes of direction that occur with forward-backward and right-left running. Participants waited for the exit in the ready position by placing their preferred front foot for running, not exceeding the marked line 50 cm behind the starting gate. Participants were instructed to touch the top of the cones (30 cm high) placed at all rotation points.

Each subject was required to sprint forward 5 m and touch the tip of the cone with the right hand. Then she performed a lateral shuffle to the left 2.5 m, and touched the tip of the cone with the left hand. Subject then changed direction and shuffled 5 m to the right to touch the tip of the cone with her right hand. She then shuffled 2.5 m to the left to touch the tip of the cone in the middle with her right hand. Finally, the subject back-peddled 5 m, passing through the finish point. Participants covered a sum total distance of 20m. 3 trial rights were given for each athlete. The subjects were allowed 3 minutes of rest between each run. By writing the measurement results in seconds, the best time obtained in three trials was recorded. Any subject who crossed one foot in front of the other, failed to touch the tip of the cone, and/or failed to face forward throughout had to repeat the test [15, 32, 33].

Statistical Analysis

Statistical analyzes of the data obtained as a result of the research were obtained using the "IBM SPSS 23.0 (IBM Corp., Armonk, NY, USA)" package program. After descriptive statistics of the data were made, normality analysis was performed for the data set.

For the homogeneity of the research data, the normal distribution of the data was tested with the "Skewness-Kurtosis" and "Shapiro Wilks" tests. As a result of this test, it was determined that the distributions were normal. For this reason, "Independent Samples T Test", which is one of the parametric tests, was used to analyze the difference between the groups. Effect size (ES) was also estimated for main effects and interaction by calculating partial eta squared values using the SPSS 23.0 statistical package. All tests taken were expressed as median (min-max), mean and standard deviation (SD) values. The degree of significance was determined as "$p < 0.05$" in the study.

Results

Table 3 shows that the average age of the athletes participating in the study was 13,29 ± 1,96 years, an average height of 159,38 ± 12,89 cm, and body weight 62,37 ± 20,55 kg.

The findings of the Independent Samples T-Test results regarding the analysis of the data in this study are as follows.

In table 4, according to the results we analyzed, the differences revealed by core and basketball training in independent sample groups; although there was a mathematical difference between the groups in the measurements of the sprint (EB=0.022; p=.585; 2.36%) and vertical jump (EB=0.172; p=.111; 21.23%) tests, this difference was not statistically significant ($p>0.05$). However, there was a statistically significant difference in favor of EG in the measurements of agility (EB=0.257; p=.045) test ($p<0.05$), this difference showed improvement by 10.33%.

Table 3. Descriptive data of all participants

Demographic features	n	X̄	SS
Age (years)	16	13.29	1.96
Height (cm)	16	159.38	12.89
Body weight (kg)	16	62.37	20.55

Table 4. Findings of difference between groups

		CG	EG	T test			
Biomotoric abilities	**N**	**X̄±SS**	**X̄±SS**	**t**	**p**	**ES**	**%Δ**
Sprint (20m)	16	4.06±.1253	3.96±.4704	.559	.585	0.022	2.36
Vertical Jump	16	28.25±4.528	34.25±8.876	-1.703	.111	0.172	21.23
Agility	16	14.292±.7475	12.815±1.7477	2.199	.045*	0.257	10.33

ES: Effect Size; * The difference is statistically significant at the p<0.05 level. %Δ: percentage of difference between measurements

Discussion

In the world of exercise and sports, the debate about the benefits of core strengthening for both athletes and sedentary individuals has continued from the past to the present and is still a current issue. In basketball, which is one of the performance sports, it is emphasized that endurance, muscle strength, sprint speed, agility and jumping ability are at the forefront in terms of game characteristics. Emphasizing the importance of core training for the improvement and development of these abilities, experts said that core programs are important especially for children in terms of gaining sports-specific skills and benefiting postural control. From this point of view, in this study, an answer was sought to the question of how the application of a core stability program in addition to the basic basketball training program would have an effect on explosive strength parameters.

Although there were improvements in the parameters of sprint (2.36%) and vertical jump (21.23%) from explosive strength according to the training pre-test and post-test results between the groups. These results were not significant as they did not differ between the groups (p>0.05). However, the improvement in the agility parameter (10.33%) represented a significant result in favor of EG (p<0.05). When the literature on the subject was reviewed, Doğan and Savaş [18] stated that their core training activities benefited the static-dynamic balance and basketball psychomotor development of basketball players aged 12-14. They also emphasized that core training should be an integral part of basic training programs for the continuity of development. In his study, Sannicandro [20] aimed to examine the effects of an integrative core stability training on jumping and sprint performance in young basketball players. He stated that the experimental group showed significant improvements in all parameters during the two time periods, but the control group showed significant improvement only in the 10m parameter. When we examined the core training studies in different performance sports, Hoshikawa et al. [34], according to the results of the study in which they looked at the effects of stabilization training on trunk muscle and physical performance in young male football players, reported that adding stabilization exercise to soccer training does not increase trunk muscle, but improves hip extensor strength and vertical jump performance in early adolescence soccer players. Ozmen and Aydogmus [35] stated that if we observe the changes brought about by core strength training in core endurance, dynamic balance and agility parameters in adolescent badminton players, significant gains were observed in Star Excursion Balance and core endurance aspects, but no change was observed in agility. Allen et al. [19], who examined the effect of core endurance interventions on trunk muscle endurance tests in school-aged children, except for performance sports, found that there were significant increases in muscular fitness test performance for each measured test result. Considering the risk of low back pain that starts in childhood, they stated that in terms of the results of the study, medium to high-intensity dynamic core exercises can be added for children and adolescents during their warm-up in physical education classes in order to improve trunk and core muscle endurance. Oliver et al. [23] stated that core muscle activations will help reduce injury rates, since young people are always at risk of musculoskeletal injuries while doing physical activity. In this context, in their study, they concluded that applying core stability programs to a basic physical education curriculum is beneficial for all children.

This study showed similar results with other studies. We can say that well-planned, controllable and regular core stabilization training has a positive effect by improving biomotor skills. It can be said that it provides a positive benefit in the movement component that requires agility by providing trunk and spine balance, especially in children and young people.

Limitations of the study

Factors such as the difficult conditions caused by the covid-19 pandemic, the small age children in the study group, and the distance of the basketball school from the city center determine the limitations of the study.

Conclusions

As a result of all the results obtained it has been stated that core stabilization training programs are important for every age group and for any sport branch. It has been proven by the studies that core training has important effects on improving biomotor skills, physical fitness parameters, acquired postural posture, gaining a solid body and preventing injury risks.

This study also showed that core stabilization training applied in a short time improves explosive strength parameters in children. Therefore, it has been demonstrated that making these trainings a routine is especially important in terms of sportive performance, as stated in the literature. In future studies, long-term and different stabilization study models can be added at monthly intervals. You can also compare different genders with different age groups.

Acknowledgements

I would like to thank students who participated in the study.

References

1. Policastro F, Accardo A, Marcovich R, Pelamatti G, Zoia S. Relation between motor and cognitive skills in italian basketball players aged between 7 and 10 years old. *Sports*, 2018;6(3):1–8. https://doi.org/10.3390/sports6030080
2. Nikolaidis PT, Clemente FM, Torres-Luque G & KB. Repeated sprint ability exercise in a 9-year-old basketball players: effect of change of direction. *Ann Med Health Sci Res*. 2017;7(6):15–9.
3. Ronda LT, Cuzzolin F. Strength Training for Basketball: A Methodological Framework Based on Basketball and Player's Needs. In: Laver L, Kocaoglu B, Cole B, Arundale AJH, Bytomski J, Amendola A, editors. *Basketball Sports Medicine and Science*, Berlin, Heidelberg: Springer Berlin Heidelberg; 2020, p. 779–89. https://doi.org/10.1007/978-3-662-61070-1_61
4. Vigo A, Viviani F. The adolescent basketball player: the importance of some anthropometric characteristics for speed, resistance, power and agility. *Antrocom Online J Anthropol*. 2020;16(2):85–95.
5. Andrejić O, Tošić S, Knežević O. Acute Effects Of Low-And High- Volume Stretching On Fitness Performance In Young Basketball Player. *Orig Artic*. 2011;2012(1):11–6.
6. Noyes FR, Barber-Westin SD, Smith ST, Campbell T, Garrison TT. A training program to improve neuromuscular and performance indices in female high school basketball players. *J Strength Cond Res*. 2012;26(3):709–19. https://doi.org/10.1519/JSC.0b013e318228194c
7. Latorre Román PÁ, Villar Macias FJ, García Pinillos F. Effects of a contrast training programme on jumping, sprinting and agility performance of prepubertal basketball players. *J Sports Sci*. 2018;36(7):802–8. https://doi.org/10.1080/02640414.2017.1340662
8. Trunić N, Mladenović M. The Importance Of Selection In Basketball. Sport - Sci Pract. 2014;4(2):65–81.
9. Balěiunas M, Stonkus S, Abrantes C, Sampaio J. Long term effects of different training modalities on power, speed, skill and anaerobic capacity in young male basketball players. *J Sport Sci Med*. 2006;5(1):163.
10. Kamandulis S, Venckunas T, Masiulis N, Matulaitis K, Balčiunas M, Peters D, et al. Relationship between general and specific coordination in 8- to 17-year-old male basketball players. *Percept Mot Skills*. 2013;117(3):821–36. https://doi.org/10.2466/25.30.PMS.117x28z7
11. Bogdanis GC, Ziagos V, Anastasiadis M, Maridaki M. Effects of two different short-term training programs on the physical and technical abilities of adolescent basketball players. *J Sci Med Sport*. 2007;10(2):79–88. https://doi.org/10.1016/j.jsams.2006.05.007
12. Faigenbaum AD, French DN, Lloyd RS, Kraemer WJ. Strength and power training for young athletes. In: *Strength and Conditioning for Young Athletes*. 2019. P. 131–54. https://doi.org/10.4324/9781351115346-7
13. Faigenbaum AD. Strength training for children and adolescents. / Entrainement de renforcement musculaire pour les enfants et les adolescents. *Clin Sports Med*. 2000;19(4):593–619. https://doi.org/10.1016/S0278-5919(05)70228-3
14. Small EW, McCambridge MT, Benjamin HJ, Bernhardt DT, Brenner JS, Cappetta CT, et al. Strength training by children and adolescents. *Pediatrics*, 2008;121(4):835–40. https://doi.org/10.1542/peds.2007-3790
15. Scanlan AT, Wen N, Pyne DB, Stojanović E, Milanović Z, Conte D, et al. Power-related determinants of modified agility T-test performance in male adolescent basketball players. *J Strength Cond Res*. 2021;35(8):2248–54. https://doi.org/10.1519/JSC.0000000000003131
16. Akuthota V, Ferreiro A, Moore T, Fredericson

M. Core Stability Exercise Principles: *Current Sports Medicine Reports*, 2008;7:39–44. https://doi.org/10.1097/01.CSMR.0000308663.13278.69
17. Hibbs AE, Thompson KG, French D, Wrigley A, Spears I. Optimizing performance by improving core stability and core strength. *Sport Med.* 2008;38(12):995–1008. https://doi.org/10.2165/00007256-200838120-00004
18. Dogan O, Savaş S. Effect of an 8-Weeks Core Training Program Applied to 12-14 Years Old Basketball Players on Strength, Balance and Basketball Skill. *Pakistan J Med Heal Sci.* 2021;15(2):823–9.
19. Allen BA, Hannon JC, Burns RD, Williams SM. Effect of a core conditioning intervention on tests of trunk muscular endurance in school-aged children. *J Strength Cond Res.* 2014;28(7):2063–70. https://doi.org/10.1519/JSC.0000000000000352
20. Sannicandro I, Cofano G, Piccinno A. Can the Core Stability Training Influences Sprint and Jump Performances in Young Basketball Players? *Adv Phys Educ.* 2020;10(03):196–206. https://doi.org/10.4236/ape.2020.103017
21. Bagherian S, Ghasempoor K, Rahnama N, Wikstrom EA. The effect of core stability training on functional movement patterns in college athletes. *J Sport Rehabil.* 2019;28(5):444–9. https://doi.org/10.1123/jsr.2017-0107
22. Sannicandro I, Cofano G. Core Stability Training and Jump Performance in Young Basketball Players. *Int J Sci Res.* 2017;6(5):479–82. https://doi.org/10.21275/ART20173282
23. Oliver GD, Adams-Blair HR, Dougherty CP. Implementation of a Core Stability Program for Elementary School Children. *Athl Train Sport Heal Care.* 2010;2(6):261–6. https://doi.org/10.3928/19425864-20100630-01
24. Boyer C, Tremblay M, Saunders TJ, McFarlane A, Borghese M, Lloyd M, et al. Feasibility, validity, and reliability of the plank isometric hold as a field-based assessment of torso muscular endurance for children 8-12 years of age. *Pediatr Exerc Sci.* 2013;25(3):407–22. https://doi.org/10.1123/pes.25.3.407
25. Choi JH, Kim DE, Cynn HS. Comparison of trunk muscle activity between traditional plank exercise and plank exercise with isometric contraction of ankle muscles in subjects with chronic low back pain. *J Strength Cond Res.* 2021;35(9):2407–13. https://doi.org/10.1519/JSC.0000000000003188
26. Turki-Belkhiria L, Chaouachi A, Turki O, Chtourou H, Chtara M, Chamari K, et al. Eight weeks of dynamic stretching during warm-ups improves jump power but not repeated or single sprint performance. *Eur J Sport Sci.* 2014;14(1):19–27. https://doi.org/10.1080/17461391.2012.726651
27. Seitz LB, Mina MA, Haff GG. A sled push stimulus potentiates subsequent 20-m sprint performance. *J Sci Med Sport.* 2017;20(8):781–5. https://doi.org/10.1016/j.jsams.2016.12.074
28. Boz HK, Temur HB. The Relationship between Core Stability and Some Performance Parameters between Fourteen and Sixteen Year Old Group Male Long Distance Runners and Football Players. *African Educ Res J.* 2020;8(2):352–6. https://doi.org/10.30918/AERJ.82.20.076
29. Zambak Ö. Evaluation of Maximum aerobic power, shoot speed and 20m. sprint powerof football players at pre-season, mid-season. *Int J Disabil Sport Heal Sci.* 2019;2(2):72–7. https://doi.org/10.33438/ijdshs.624026
30. Stojanović N, Jovanović N, Stojanović T. The effects of plyometric training on the development of the jumping agility in volleyball players. *Facta Univ - Ser Phys Educ Sport.* 2012;10(1):59–73.
31. Yingling VR, Castro DA, Duong JT, Malpartida FJ, Usher JR, Jenny O. The reliability of vertical jump tests between the Vertec and My Jump phone application. *PeerJ.* 2018;4:1–13. https://doi.org/10.7717/peerj.4669
32. Sassi RH, Dardouri W, Yahmed MH, Gmada N, Mahfoudhi ME, Gharbi Z. Relative and absolute reliability of a modified agility t-test and its relationship with vertical jump and straight sprint. *J Strength Cond Res.* 2009;23(6):1644–51. https://doi.org/10.1519/JSC.0b013e3181b425d2
33. Corbett L. *The relationship of a modified agility T-Test with stretch-shortening cycle and straight sprint acceleration.* [Doctoral dissertation]. University of Wales; 2011.
34. Hoshikawa Y, Iida T, Muramatsu M, Ii N, Nakajima Y, Chumank K, et al. Effects of stabilization training on trunk muscularity and physical performances in youth soccer players. *J Strength Cond Res.* 2013;27(11):3142–9. https://doi.org/10.1519/JSC.0b013e31828bed36
35. Ozmen T, Aydogmus M. Effect of core strength training on dynamic balance and agility in adolescent badminton players. *Journal of Bodywork and Movement Therapies*, 2016;20:565–70. https://doi.org/10.1016/j.jbmt.2015.12.006

Information about the author:

Nurkan Yılmaz; https://orcid.org/0000-0002-8845-7093; nurkan.yilmaz@inonu.edu.tr; Department of Physical Education and Sports Teaching, Inonu University; Malatya, Turkey.

Cite this article as:
Yılmaz N. Investigation of the effect of isometric core strength training in addition to basic basketball trainings on explosive power in children aged 9-17. *Pedagogy of Physical Culture and Sports,* 2022;26(2):75–82.
https://doi.org/10.15561/26649837.2022.0201

Received: 07.12.2021
Accepted: 21.01.2022; Published: 30.04.2022

ORIGINAL ARTICLE

The role of gender in predicting life satisfaction of the interest in physical education lesson

Ahmet E. Sağın

Health Sciences Institute, Inonu University, Malatya, Turkey

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim In this study, it was aimed to investigate the relationship between the level of interest in physical education lesson and life satisfaction of students studying in secondary schools.

Material and Methods The research group consisted of 421 students in total 52.3% (n=220) were male students and 47.7% (n = 201) were female students. Structural equation model was used in the analysis of research data.

Results The effect of interest in physical education lesson on life satisfaction was found to be 19.8% (R^2 = .198, $p <0.05$). In the gender variable, the effect of interest in physical education lesson on life satisfaction in girls is 12.8% (R^2 = .128), whereas it is 25.7 (R^2 = .257) in boys. According to the model, as the level of interest in physical education lesson of students studying in secondary school increases, their life satisfaction increases. While it is concluded that the interest level of students studying in secondary schools in physical education and sports lessons positively predicts their life satisfaction, this rate is higher in male students.

Conclusions Since the participation of students in physical education and sports activities contributes to the multifaceted development and life satisfaction of students, it is necessary to increase the interest of students in physical education lessons and especially to engage female students. It is very important for physical education teachers to provide an environment for student participation in physical education and sports lessons. School-based interventions that can increase female students' participation and interest in physical education and sports lessons can be effective.

Keywords: life satisfaction, interest in physical education, gender and sports, structural equation model

Introduction

In the psychological studies, the happiness of the individual is indicated by the concept of subjective well-being. Subjective well-being (happiness), which reflects the degree of experience of the individual's life or means evaluating the life of the individual, is considered as a versatile structure that includes both cognitive and emotional factors [1]. The affective dimension of subjective well-being is divided into 2 items as positive affect (joy, interest, cheer, trust, excitement, etc.) and negative affect (grief, sadness, anxiety, anger, etc.), while the cognitive dimension is life satisfaction [2]. Life satisfaction is the individual's self-assessment in the light of the criteria he/she has determined [3]. While life satisfaction [4], which is an important structure in positive psychology, is examined in detail in adults, life satisfaction of children and young people has recently begun to draw attention [5, 6]. Life satisfaction in adults increases to a certain age and then decreases. With this decrease, cognitive, physical and social problems emerge [7-10].

Increasing the quality of life has been a target for the individual, society, nation and the world for a long time [11]. Life satisfaction can be an important factor especially in reducing the problematic behavior of young people [12]. At this point, school environments can contribute to increasing life satisfaction because school environments are important not only for the academic development of students but also for their non-academic development [13]. School can be an important area for young people's life satisfaction [14] and can make important contributions to their lives [15]. Relationship between students at school, teacher-student relationship, order and discipline, parental involvement in education can play critical roles in determining students' life satisfaction [16]. As students' life satisfaction increases, they develop more positive attitudes towards school and teacher [4], and their academic achievement [13], self-esteem, focus of internal control, and extraversion raise [17]. On the other hand, those with higher life satisfaction experience less depression [6], less stress [6, 15], less anxiety and worry [7, 17]. Therefore, it is important to increase students' life satisfaction. Otherwise, when life satisfaction is low, the probability of being addicted [18, 19], carrying weapons or knives, engaging in a fight [19] suicidal ideation [7, 9, 20], depression [21, 22] increases.

Motivation is an important force in starting and maintaining learning behaviors. Because it becomes harder for students to learn unless they are motivated [23]. Interest can make a critical contribution to

doi:10.15561/26649837.2022.0202

increase the effectiveness of learning processes. The interest not only increases the student's focus on the lesson, but also makes him willing [24] and has a strong influence on learning [25]. It is an important component that contributes to psychological well-being in all life stages as well as its effect on learning [26]. Interest to physical education and sports lessons is an important factor in creating the learning environment [27-29]. At this point, it is very important to attract students' attention to physical education and sports lessons. According to Chen, Durst and Pangrazi [30], physical activities must provide new information, require a high level of attention, refer to research and provide a fun environment for students to attract their attention. In a traditional classroom environment, students are expected to gather around a table and complete a given study. Physical education and sports lessons offer environments where students try to show their talents and skills, where sports activities are at the forefront and where dynamic interaction matters [31]. Physical education and sports lessons play a distinctive role in developing children's mobility skills and gaining physical competence [32]. Sports and physical activity help the individual in personal pleasure, personal development, social adaptation and social change [33]. Physical activity supports the healthy development of children [34-36] and makes them feel better psychologically [37]. In physical education lessons, students have more fun and their perception of pleasure increases, and they also have the opportunity to socialize [31, 35, 38]. Physical education and sports activities can also benefit academic performance as it affects children's social leadership, participation in decision-making processes and increasing their concentration [32]. In the researches, it is seen that students define physical education lessons as a fun, loved and joyful lesson [39, 40].

It is thought that as a result of the students having fun and enjoyable time in the lessons, their interest in the lesson increases, and in parallel to this, it may positively affect their life satisfaction. In this study, the relationship between the interest level and life satisfaction of students studying in secondary schools was studied.

Materials and Methods

Relational screening model was used in this study in which the relationship between secondary school students' level of interest in physical education and life satisfaction was examined. Relational screening model was preferred in order to give an idea about cause-effect relationship between two or more variables [41, 42]. The relationship between students' interest in physical education lesson and their life satisfaction was tested using the structural equation modeling (SEM). SEM is a powerful analysis method used in theory development by examining the relationships between variables [43].

Participants

421 students attending the secondary school participated in the study. While 52.3% (n = 220) of the students participating in the study were female students, 47.7% (n = 201) were male students. The study group was distributed as 23% (n = 98) in the 5th grades, 26.1% (110) in the 6th grades, 23.8% (n = 100) in the 7th grades, and finally 26.8% (n = 113) in the 8th grades. Required legal permission was obtained from Çanakkale Onsekiz Mart University Graduate School for this research (Ethics committee decision no: 2021-13/19).

Research Design

Data Collection Tools

Life Satisfaction Scale: Life satisfaction for children scale, which was developed by Gaderman et al. [44] and adapted to Turkish culture by Altay and Ekşi [45], was used to determine the life satisfaction of students studying in secondary school. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were performed for the construct validity of the scale. According to AFA results, since Bartlett test result is significant ($\chi2$ = 822.101, df: 10, p <.001) and Kaiser-Meyer-Olkin (KMO) coefficient is .834, the data set was found to be suitable for factor analysis. It was determined that the variance rate explained by the scale was 61.030%. Cronbach's Alpha reliability coefficient of the scale was found to be .851. As a result of the CFA, it was observed that the item factor loads varied between .57 and .88. According to the results of CFA, $\chi2$ / sd (2.827), GFI (.987), CFI (.989), NFI (.983), IFI (.989) and RMSEA (.066) values were found. It was determined that the scale has perfect fit reference values [46, 47].

The Scale of Interest in Physical Education Lesson: It was developed by Uğraş and Temel in order to determine the interest levels of secondary school students for physical education and sports lesson [48]. According to EFA results, since Bartlett test result is significant ($\chi2$ = 3225,060, df: 45, p <.001) and Kaiser-Meyer-Olkin (KMO) coefficient is 941, the data set was found to be suitable for factor analysis. It was determined that the variance rate explained by the scale of interest in the physical education lesson was 66.662%, and the factor loads were between .71 and .83. Since the results of the DFA analysis were out of acceptable values, two modifications were made. Acceptable values were achieved after modification ($\chi2$/sd = 4.786, GFI = .948, CFI = .974, NFI = .965, IFI = .974, RMSEA = .80).

Statistical Analysis

SPSS 23 and AMOS 23 statistics programs were used to analyze the data. Before determining whether the data are suitable for the structural equation model, 30 questionnaires with missing, erroneous and extreme values were removed and the process was continued with a total of 421 data sets. For the normality assumption of the data, skewness and kurtosis values were examined. After determining that EFA, CFA and Cronbach's Alpha reliability coefficients met the necessary conditions for Structural Equation Modeling (SEM), analyzes were performed. While SPSS 23 was used for EFA with descriptive statistics, AMOS 23 was used in CFA and SEM analysis. $\chi 2$/sd, GFI, CFI, NFI, IFI and RMSEA values were examined to test the YEM model.

Results

As it can be seen in Table 1, the average scores of the students in the scales of interest in physical education and life satisfaction showed a normal distribution. For this reason, parametric tests were preferred [49]. It has been determined that there is a moderate significant correlation ($r = .463$, $p < .01$) between interest in physical education lesson and life satisfaction.

After examining the relationship between the interest in physical education lesson and the life satisfaction of students, the predictive effect of the "interest in physical education lesson" variable on the "life satisfaction" variable was tested by path analysis. The model tested is shown in Figure 1.

It has been determined that the model examining the effect of interest in physical education lesson on life satisfaction has acceptable fit indices (χ^2/sd = 2.930, GFI = .927, CFI = .964, IFI = .899, NFI = .946, RMSEA = .068). The path model showing the relation of interest in physical education lesson is shown in table 2.

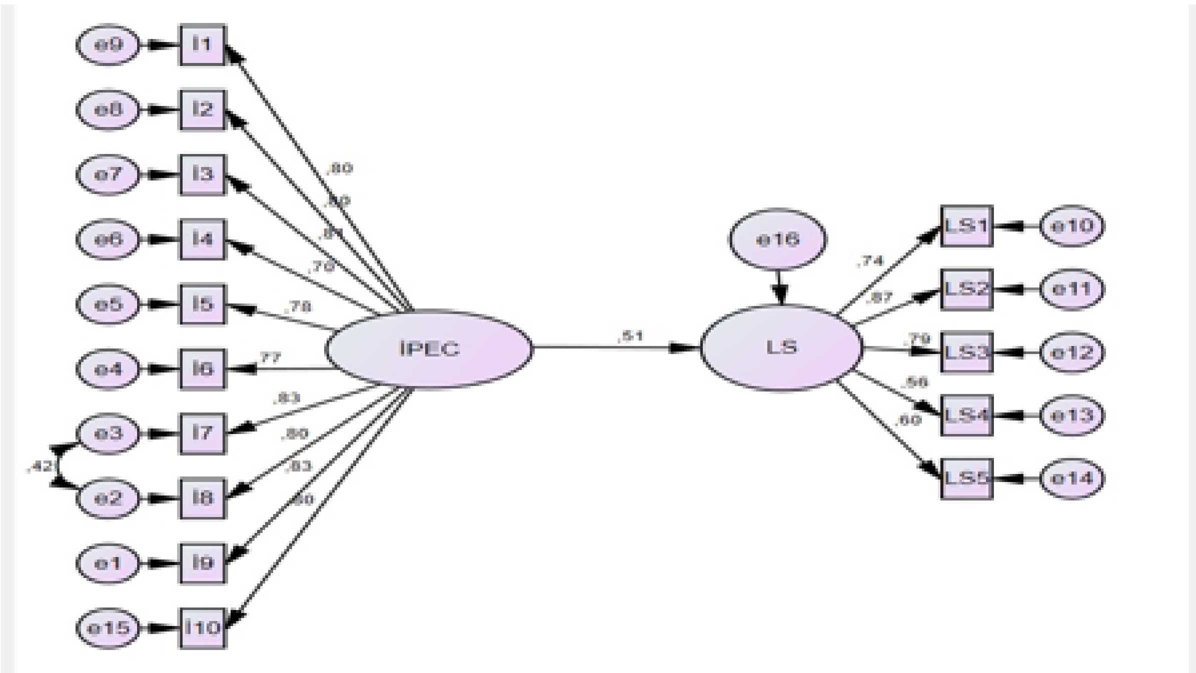
According to Table 2, it has been observed that the interest in physical education lesson affected life satisfaction emphatically and unquestionably ($\beta = .51$, $p < .05$) and is statistically significant. It has been determined that the effect of interest in physical education lesson on life satisfaction is 19.8% ($R^2 = .198$). After the analysis of the interest in physical education lesson predicting life satisfaction, the path analysis for the interest of female students in physical education lesson is shown in Figure 2.

The model, which examines the effect of interest of female students in physical education lesson on life satisfaction, has been found to have acceptable fit indices as a result of modifications (χ^2/sd = 2.154, GFI = .899, CFI = .937, IFI = .938, NFI = .890, RMSEA = .073). The path model showing the relation of

Table 1. Arithmetic mean, standard deviation, skewness, kurtosis and correlation values of variables

Variables	X	SS	Skewness	Kurtosis	Correlation
Interest in Physical Education Lesson	3.90	0.99	-1.03	0.45	1
Life Satisfaction	3.67	0.96	-0.72	-0.11	.445**

Note: ** - p <.05



IPEC: Interest in physical education lesson LS: life satisfaction

Figure 1. Path analysis of the interest in physical education lesson for predicting life satisfaction

interest in physical education lesson is shown in table 2.

According to Table 3, it has been observed that the interest in physical education lesson positively and significantly (β=.45, $p < .05$) affects life satisfaction and is significant statistically. It has been determined that the effect of interest in physical education lesson on girls' life satisfaction is 12.8% ($R^2 = .128$). After analyzing the interest of female students in physical education lesson on life satisfaction, the path analysis of male students' interest in physical education course is shown in Figure 3.

The model examining the effect of male students' interest in physical education lesson on life satisfaction was found to have acceptable fit indices as a result of the modifications made ($\chi2$ / sd = 2.126, GFI = .897, CFI = .966, IFI = .966, NFI = .937, RMSEA = .075). The path model showing the relation of interest in physical education lesson is shown in table 4.

Table 2. Standardized regression results regarding the effect of interest in physical education lesson on life satisfaction

Path	**Path Coefficient (β)**	**Standardized estimate (Estimate)**	**Standard Error (S.E)**	**Critical Rate (C.R)**	**Significance Value (p)**
Interest in Physical Education Lesson → Life satisfaction	.5	.446	.049	9.148	***

Note: *** - p< .05

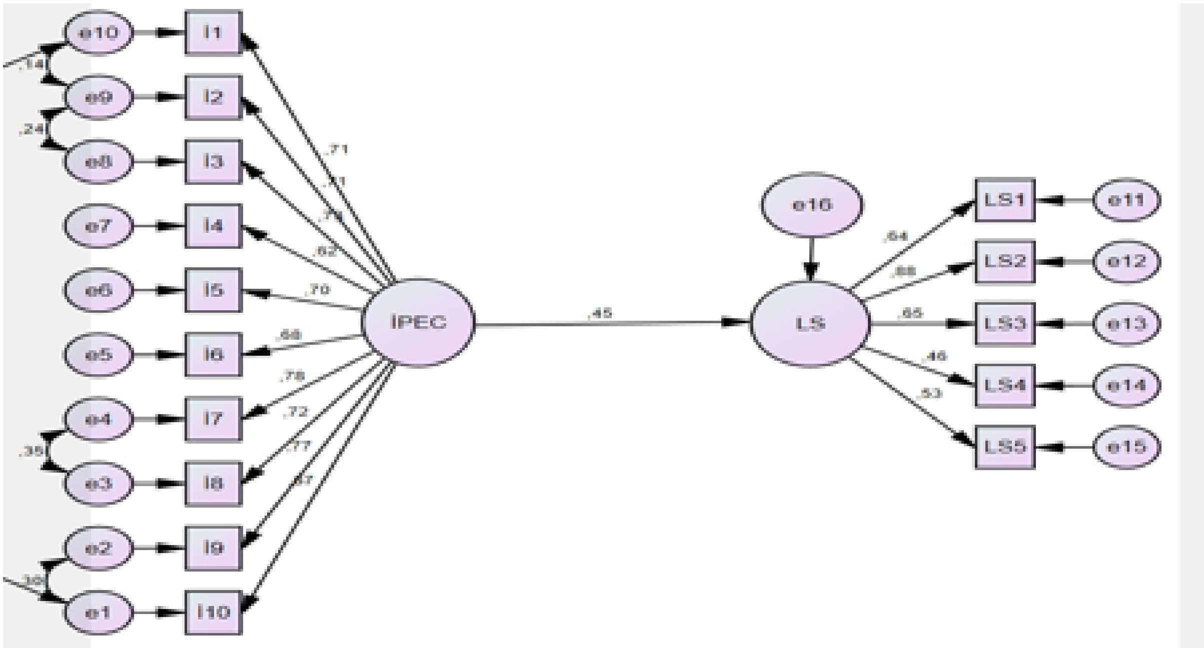


Figure 2. Path analysis for the interest of female students in physical education lesson on predicting life satisfaction

Table 3. Results on the effect of female students' interest in physical education lesson on life satisfaction

Path	**Path Coefficient (β)**	**Standardized estimate (Estimate)**	**Standard Error (S.E)**	**Critical Rate (C.R)**	**Significance Value (p)**
Interest in Physical Education Lesson → Life satisfaction	.45	.387	.077	5.005	***

Note: ***- p< .05

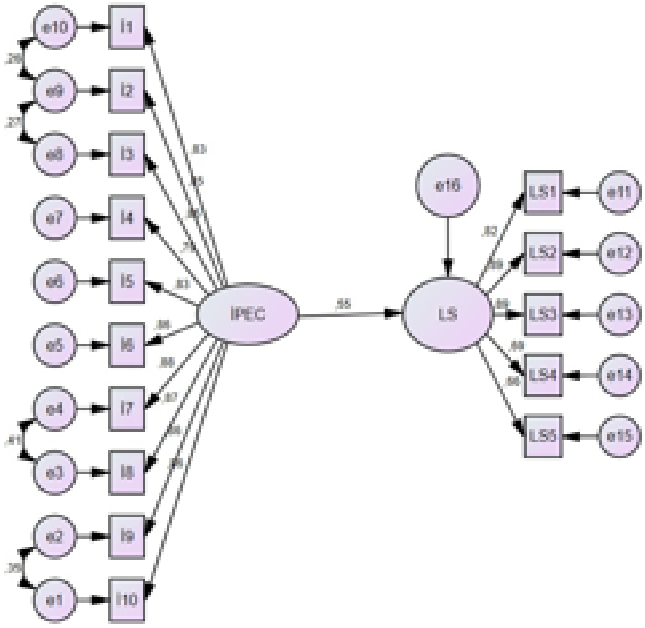


Figure 3. Path analysis of male students' interest in physical education lesson on predicting life satisfaction

Table 4. Results on the effect of male students' interest in physical education lesson on life satisfaction

Path	Path Coefficient (β)	Standardized estimate (Estimate)	Standard Error (S.E)	Critical Rate (C.R)	Significance Value (p)
Interest in Physical Education Lesson → Life satisfaction	.55	.482	.064	5.005	***

Note: *** - p< .05

According to Table 4, it has been observed that the interest in physical education lesson affect life satisfaction positively and significantly and is statistically significant. The effect of interest in physical education lesson on life satisfaction in male students was found to be 25.7% (R^2 = .257).

Discussion

In the study, the relationship between secondary school students' level of interest in physical education lesson and their satisfaction with life was examined with the structural equation model. It was concluded that the level of interest of students studying in secondary schools to physical education and sports lessons predicted their life satisfaction positively and significantly. In the studies conducted, the health development, psychological development, socialization opportunities and academic performance of students participating in sports activities and physical activities are positively affected [32, 34, 35, 37]. Sportive activities encourage compliance with social rules and keep alcohol, violence, illegal substance abuse away. It increases self-esteem. It gives fun and pleasure. It gives life experience. It allows you to make more friends. It helps to improve mental health [50-54]. Similarly, individuals who participate in physical activities after the youth period feel more competent, protect their self-esteem and increase the chance of staying healthy and fit. However, individuals who stay away from sports and physical activity over time have more cognitive, physical and social difficulties compared to those who do sports. Therefore, it can be said that physical activity increases life satisfaction and those who move more and participate in physical activities have more life satisfaction than those who do not participate [8, 55-58]. Therefore, in this study, it is possible that the interest of secondary school students in physical education lesson affected life satisfaction positively.

In our study, when we look at the relationship between the level of interest in physical education lesson and life satisfaction according to the gender variable, it was seen that the level of interest in men affects their life satisfaction more. While the participation of students in physical education and sports activities is high at young ages, participation rates decrease with adolescence [59-61]. While some studies do not differ by gender [61], most of the studies show that the participation rates of girls in physical education and sports activities decrease compared to boys [59, 60, 62, 63]. In a study investigating girls' participation in physical activities in secondary school, Robbins, Pender and Kazanis [64] found that female students had a sense of self-awareness and inadequacy. The study conducted by Whitehead and Biddle [65] between forty-seven girls among the ages of 14-16 reveals that the participation of adolescent girls in physical activities is not high due to social effects and social norms. While Fisette [66] says that female students are ashamed in physical education and sports lessons and they fall behind in the background, according to Kirk [67] male students with high skills come into prominence due to the creation of a skill-oriented lesson environment in physical education and sports lessons. It is very important to create a physical education lesson environment that meets the unique needs of girls in such an environment [68]. In this study, it can be interpreted that female students have less interest in physical education lesson than male students, and its effect on life satisfaction also decreases.

In order to increase the life satisfaction of children and ensure their participation in sports, they should be ensured to participate in physical education and sports activities from a young age [69]. Therefore, environments where students will be interested in physical education and sports lessons should be created. Physical education lessons have quite different alternatives to attract students. Students' interest in the lesson may increase with the presence of elements such as innovation, exciting and stimulating activities, physical activity and social participation [23, 70, 71]. Domville et al. [72] state that their desire to participate as long as students enjoy in physical education and sports lessons. For this reason, physical education and sports lesson should increase the students' feeling of instant enjoyment [62, 73]. In order to increase students' interest in physical education and sports lessons, Chen et al. [74] conceptualized the lesson to cover 5 sub-dimensions. These are: innovation (the difference between current knowledge and knowledge to be learned), attention (cognitive participation), challenge (difficulty), discovery (features of learning tasks that encourage the student to explore their environment) and pleasure (positive emotion experienced by the student). In order to attract the attention of students to physical education and sports lessons, besides the individual preferences of the students and external factors, the most important task belongs to physical education teachers [72]. Researches show that attitude levels [48, 75, 76] are already positive, which is one of the important factors affecting children's participation and maintenance in physical education and physical activity [69, 77-79]. At this point, the classroom environment created by physical education teachers will increase the interest of the students and ensure that their attendance is permanent [80, 81]. In this way, it can be ensured that students' interest in physical education lessons are increased and their life satisfaction is increased. It can be stated that by increasing students' interest in the lesson and indirectly their life satisfaction, it will have a positive effect on many factors such as academic success, peer relations, school belonging. As a result, it was concluded that the level of interest of students studying in secondary schools to physical education and sports lessons predicted their life satisfaction positively. At the same time, it was determined that male students' interest levels of physical education lessons predicted their life satisfaction more. As students' participation in physical education and sports activities contributes to the multifaceted development and life satisfaction of students, increasing the interest of students in physical education lessons becomes important. It is very important for physical education teachers to provide an environment for student participation in physical education and sports lessons. School-based interventions that can increase female students' participation and interest in physical education and sports lessons can be effective [68].

Limitations

It was concluded that the level of interest of students studying in secondary schools to physical education and sports lessons predicted their life satisfaction strongly. By virtue of this result, it can be misleading to interpret the relationship between physical education and life satisfaction only by looking at the levels of physical education and physical activity. Our study emphasizes that the level of interest in physical education and sports can have a significant effect on students' life satisfaction. Our study is not representative nationally and data were collected from a specific region in Turkey.

Acknowledgement

We gratefully acknowledge the help of all the participant who took part in the study.

Conflict of interests

The authors state that there is no conflict of interest

References

1. Diener E. Subjective Well-Being. In: Diener E, editor. *The Science of Well-Being*, vol. 37, Dordrecht: Springer Netherlands; 2009. P. 11–58. https://doi.org/10.1007/978-90-481-2350-6_2
2. Diener E, Suh EM, Lucas RE, Smith HL. Subjective well-being: Three decades of progress. *Psychological Bulletin*. 1999;125(2); 276. https://doi.org/10.1037/0033-2909.125.2.276
3. Diener ED, Emmons RA, Larsen RJ, Griffin S. The satisfaction with life scale. *Journal of Personality Assessment*. 1985;49(1):71– 75. https://doi.org/10.1207/s15327752jpa4901_13
4. Gilman R, Huebner ES. Characteristics of adolescents who report very high life satisfaction. *Journal of Youth and Adolescence*. 2006;35(3):293–301. https://doi.org/10.1007/s10964-006-9036-7
5. Danielsen AG, Samdal O, Hetland J, Wold B. School-related social support and students' perceived life satisfaction. *The Journal of Educational Research*, 2009;102(4):303–320. https://doi.org/10.3200/JOER.102.4.303–320
6. Proctor CL, Linley PA, Maltby J. Youth life satisfaction: A review of the literature. *Journal of Happiness Studies,* 2009;10(5):583–630. https://doi.org/10.1007/s10902-008-9110-9
7. Blanchflower DG, Oswald AJ. Is well-being U-shaped over the life cycle?. *Social Science & Medicine*, 2008;66(8):1733–1749. https://doi.org/10.1016/j.socscimed.2008.01.030
8. Borg C, Hallberg IR, Blomqvist K. Life satisfaction among older people (65+) with reduced self-care capacity: the relationship to social, health and financial aspects. *Journal of Clinical Nursing*, 2006;15(5):607–618. https://doi.org/10.1111/j.1365-2702.2006.01375.x
9. Heisel MJ, Flett GL. Purpose in life, satisfaction with life, and suicide ideation in a clinical sample. Journal of *Psychopathology and Behavioral Assessment,* 2004;26(2):127–135. https://doi.org/10.1023/B:JOBA.0000013660.22413.e0
10. Jovanović V, Joshanloo M. The determinants of life satisfaction in Serbia: Findings from the Gallup World Poll. *Intnl J Wellbeing*, 2019;9:43–60. https://doi.org/10.5502/ijw.v9i1.751
11. Costanza R, Fisher B, Ali S, Beer C, Bond L, Boumans R,... Gayer DE. Quality of life: An approach integrating opportunities, human needs, and subjective well-being. *Ecological Economics*, 2007;61(2-3):267–276. https://doi.org/10.1016/j.ecolecon.2006.02.023
12. Sun RC, Shek DT. Life satisfaction, positive youth development, and problem behaviour among Chinese adolescents in Hong Kong. *Social Indicators Research*. 2010;95(3):455–474. https://doi.org/10.1007/s11205-009-9531-9
13. Virtanen M, Kivimäki M, Luopa P, Vahtera J, Elovainio M, Jokela J, Pietikäinen M. Staff reports of psychosocial climate at school and adolescents' health, truancy and health education in Finland. The *European Journal of Public Health*. 2009;19(5):554–560. https://doi.org/10.1093/eurpub/ckp032
14. Gilman R, Huebner ES, Laughlin JE. A first study of the Multidimensional Students' Life Satisfaction Scale with adolescents. *Social Indicators Research*. 2000;52(2):135–160. https://doi.org/10.1023/A:1007059227507
15. Abolghasemi A, Varaniyab ST. Resilience and perceived stress: predictors of life satisfaction in the students of success and failure. *Procedia-Social and Behavioral Sciences*. 2010;5,748–752. https://doi.org/10.1016/j.sbspro.2010.07.178
16. Suldo SM, Thalji-Raitano A, Hasemeyer M, Gelley CD, Hoy B. Understanding middle school students life satisfaction: Does school climate matter?. *Applied Research in Quality of Life*. 2013;8(2): 169–182. https://doi.org/10.1007/s11482-012-9185-7
17. Huebner ES. Correlates of life satisfaction in children. *School Psychology Quarterly*, 1991;6:103–11. https://doi.org/10.1037/h0088805
18. Mohamad M, Mohammad M, Mat Ali NA, Awang Z. The impact of life satisfaction on substance abuse: delinquency as a mediator. *International Journal of Adolescence and Youth*. 2018;23(1):25–35. https://doi.org/10.1080/02673843.2016.1267021
19. Valois RF, Zullig KJ, Huebner ES, Drane JW. Relationship between life satisfaction and violent behaviors among adolescents. *American Journal of Health Behavior*. 2001;25(4):353–366. https://doi.org/10.5993/AJHB.25.4.1
20. Kim HS, Kim HS. Risk factors for suicide attempts among Korean adolescents. *Child Psychiatry and Human Development*. 2008; 39(3):221–235. https://doi.org/10.1007/s10578-007-0083-4
21. Arrindell WA, Meeuwesen L, Huyse FJ. The Satisfaction With Life Scale (SWLS): Psychometric properties in a non-psychiatric medical outpatients sample. *Personality and Individual Differences*, 1991;12(2):117–123. https://doi.org/10.1016/0191-8869(91)90094-R
22. Gullone E, Cummins RA. The Comprehensive Quality of Life Scale: A psychometric evaluation with an adolescent sample. *Behaviour Change*. 1999;16(2):127–139. https://doi.org/10.1375/bech.16.2.127
23. Palmer DH. Student interest generated during an inquiry skills lesson. Journal of Research in Science Teaching: *The Official Journal of the National Association for Research in Science Teaching,* 2009;46(2):147–165. https://doi.org/10.1002/tea.20263
24. Hidi S. Interest: A unique motivational variable. *Educational Research Review*. 2006;1(2):69–82. https://doi.org/10.1016/j.edurev.2006.09.001
25. Hidi S, Renninger KA. The four-phase model of interest development. *Educational Psychologist*. 2006;41(2):111–127. https://doi.org/10.1207/s15326985ep4102_4
26. Ainley M. One Ingredient in the Mix: Interest and Psychological Well-Being. In: Efklides A, Moraitou D, editors. *A Positive Psychology Perspective on Quality of Life*, vol. 51, Dordrecht: Springer Netherlands; 2012, p. 243–58. https://doi.org/10.1007/978-94-007-4963-4_13
27. Chen A, Ennis CD. Goals, interests, and

learning in physical education. *The Journal of Educational Research*. 2004:97(6):329–339. https://doi.org/10.3200/JOER.97.6.329-339
28. Subramaniam PR. Unlocking the power of situational interest in physical education. Journal of Physical Education, *Recreation & Dance*. 2010;81(7):38–49. https://doi.org/10.1080/07303084.2010.10598507
29. Zhu X, Chen A, Ennis C, Sun H, Hopple C, Bonello Mi, Bae M, Kim S. Situational interest, cognitive engagement, and achievement in physical education. *Contemporary Educational Psychology*, 2009;34(3):221–229. https://doi.org/10.1016/j.cedpsych.2009.05.002
30. Chen A, Darst PW, Pangrazi RP. What constitutes situational interest? Validating a construct in physical education. *Measurement in Physical Education and Exercise Science*, 1999;3(3):157–165. https://doi.org/10.1207/s15327841mpee0303_3
31. Garn AC, Ware DR, Solmon MA. Student engagement in high school physical education: Do social motivation orientations matter?. *Journal of Teaching in Physical Education*. 2011;30(1):84–98. https://doi.org/10.1123/jtpe.30.1.84
32. Bailey R, Armour K, Kirk D, Jess M, Pickup I, Sandford R, Education BP. The educational benefits claimed for physical education and school sport: an academic review. *Research Papers in Education,* 2009;24(1):1–27. https://doi.org/10.1080/02671520701809817
33. Wankel LM, Berger BG. The psychological and social benefits of sport and physical activity. *Journal of Leisure Research.* 1990;22(2):167–182. https://doi.org/10.1080/00222216.1990.11969823
34. Gür K, Ergün A, Yıldız A, Yurt S, Ergün A, Kadıoglu H. Health problems of students according to Omaha problem classification scheme in a primary school. *J Nurs Res Dev*, 2008; 10(3), 1–14.
35. Smith A, Parr M. Young people's views on the nature and purposes of physical education: a sociological analysis. *Sport, Education and Society* 2007;12(1):37–58. https://doi.org/10.1080/13573320601081526
36. Sağlık TC. *School health book in health care*. Ankara: Ministry of Health; 2008. (In Turkish).
37. Biddle SJ, Fox KR, Boutcher SH, Faulkner GE. The way forward for physical activity and the promotion of psychological well-being. *Physical Activity and Psychological Well-Being*. 2001;154–168.
38. Wallhead TL, Garn AC, Vidoni C. Sport Education and social goals in physical education: relationships with enjoyment, relatedness, and leisure-time physical activity. *Physical Education and Sport Pedagogy*. 2013;18(4):427–441. https://doi.org/10.1080/17408989.2012.690377
39. Namlı A, Temel C, Güllü M. Ortaokul Metaphors produced by secondary school students related to physical education lesson. *Kastamonu Education Journal*. 2017;25(2):479–496.
40. Temel C, Güllü M. Draw a Physical Education Lesson. *Education and Science*, 2016; 41(183);351–361. https://doi.org/10.15390/EB.2016.5106
41. Fraenkel JR, Wallen NE, Hyun HH. *How To Design And Evaluate Research İn Education*. New York: McGraw-Hill; 2012.
42. Karasar N. *Science research method*. 28 Edition. Ankara: Nobel Publishing; 2015. (In Turkish).
43. Byrne BM. *Structural equation modeling with AMOS: basic concepts, applications, and programming (multivariate applications series).* New York: Taylor & Francis Group; 2010;396–7384.
44. Gadermann AM, Guhn M, Zumbo B. Investigating the Substantive Aspect of Construct Validity fort he Satisfaction with Life Scale Adapted for Children. *A Focus on Cognitive Processes*. 2010;100(1):37–60. http://dx.doi.org/10.1007/s11205-010-9603-x
45. Altay D, Ekşi H. Validity and reliability study of the life satisfaction scale for children. *The 5th International Symposium on Educational Sciences*, Istanbul: Turkey.2018;354–362. (In Turkish).
46. Hooper D, Coughlan J, Mullen M, Structural equation modelling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods*, 2008;6(1):53–60.
47. Kline RB. *Principle and practice of structural equation modelling*. 4rd ed. New York, NY: The Guilford Press; 2016.
48. Uğraş S, Temel C. Validity and reliability study for physical education course ınterest scale. *Gaziantep Üniversitesi Spor Bilimleri Dergisi*. 2020; 5(4): 413–427. https://doi.org/10.31680/gaunjss.737896
49. Uğraş S, Özen G. Investigation of relationship between attitude to physical education course and school belonging. *Pedagogy of Physical Culture and Sports,* 2020; 24(1):48–53. https://doi.org/10.15561/18189172.2020.0108
50. Joseph RP, Royse KE, Benitez TJ, Pekmezi DW. Physical activity and quality of life among university students: exploring self-efficacy, self-esteem, and affect as potential mediators. *Quality of Life Research*, 2014;23(2):659–667. https://doi.org/10.1007/s11136-013-0492-8
51. Kleszczewska D, Dzielska A, Salonna F, Mazur J. The association between physical activity and general life satisfaction in lower secondary school students: the role of individual and family factors. *Community Mental Health Journal*, 2018;54(8):1245–1252. https://doi.org/10.1007/s10597-018-0309-x
52. Shaffer DR. Wittes E, Women's precollege sports participation, enjoyment of sports, and self-esteem. *Sex Roles*. 2006;55(3-4):225–232. https://doi.org/10.1007/s11199-006-9074-3
53. Lin LI. The Psychological Effects of Primary and Middle School Students Participating in Different Exercise Events and Its Relation with Mental Health [J]. *Chına Sport Scıence And Technology*. 2000;6.
54. Woodruff AL, Schallert DL. Studying to play, playing to study: Nine college student-athletes' motivational sense of self. *Contemporary Educational Psychology*. 2008;33(1):34–57. https://doi.org/10.1016/j.cedpsych.2007.04.001
55. Dong HJ, Larsson B, Dragioti E, Bernfort L, Levin LÅ, Gerdle B. Factors Associated with Life Satisfaction in Older Adults with Chronic Pain (PainS65+). *Journal of Pain Research*. 2020;13: 475. https://doi.org/10.2147/JPR.S234565
56. Elavsky S, McAuley E, Motl RW, Konopack JF,

Marquez DX, Hu, L, Gerald JJ, Diener E. Physical activity enhances long-term quality of life in older adults: Efficacy, esteem, and affective influences. *Annals of Behavioral Medicine*. 2005;30(2);138– 145. https://doi.org/10.1207/s15324796abm3002_6
57. Elavsky S. *Physical activity, menopause, and quality of life: the role of affect and self-worth across time. Menopause* (New York, NY). 2009;16(2):265. https://doi.org/10.1097/gme.0b013e31818c0284
58. Omorou YA, Erpelding ML, Escalon H. Vuillemin A, Contribution of taking part in sport to the association between physical activity and quality of life. *Quality of Life Research*, 2013;22(8):2021–2029. https://doi.org/10.1007/s11136-013-0355-3
59. Biddle SJ, Whitehead SH, O'Donovan T.M, Nevill ME, Correlates of participation in physical activity for adolescent girls: a systematic review of recent literature. *Journal of Physical Activity and Health*. 2005;2(4):423-434. https://doi.org/10.1123/jpah.2.4.423
60. Brodersen NH, Steptoe A, Boniface DR, Wardle J. Trends in physical activity and sedentary behaviour in adolescence: ethnic and socioeconomic differences. *British Journal of Sports Medicine,* 2007;41(3):140–144. https://doi.org/10.1136/bjsm.2006.031138
61. Farooq MA, Parkinson KN, Adamson AJ, Pearce MS, Reilly JK, Hughes A, Janssen X, Reilly J J. Timing of the decline in physical activity in childhood and adolescence: Gateshead Millennium Cohort Study. *British Journal of Sports Medicine,* 2018;52(15):1002–1006. https://doi.org/10.1136/bjsports-2016-096933
62. Mercier K, Donovan C, Gibbone A, Rozga K. Three-year study of students' attitudes toward physical education: grades 4–8. *Research Quarterly for Exercise and Sport*, 2017;88(3):307–315. https://doi.org/10.1080/02701367.2017.1339862
63. Pate RR, Stevens J, Webber LS, Dowda M, Murray DM, Young DR, Going S. Age-related change in physical activity in adolescent girls. *Journal of Adolescent Health*, 2009;44(3):275–282. https://doi.org/10.1016/j.jadohealth.2008.07.003
64. Robbins LB, Pender NJ, Kazanis AS. Barriers to physical activity perceived by adolescent girls. The *Journal of Midwifery & Women's Health*. 2003;48(3):206–212. https://doi.org/10.1016/S1526-9523(03)00054-0
65. Whitehead S, Biddle S. Adolescent girls' perceptions of physical activity: A focus group study. *European Physical Education Review*, 2008;14(2):243–262. https://doi.org/10.1177/1356336X08090708
66. Fisette JL. 'Are you listening?': Adolescent girls voice how they negotiate self-identified barriers to their success and survival in physical education. *Physical Education and Sport Pedagogy*. 2013;18(2):184–203. https://doi.org/10.1080/17408989.2011.649724
67. Kirk D. Framing quality physical education: the elite sport model or Sport Education?. *Physical Education & Sport Pedagogy*. 2004;9(2):185–195. https://doi.org/10.1080/1740898042000294985
68. Camacho-Minano MJ, LaVoi NM, Barr-Anderson DJ. Interventions to promote physical activity among young and adolescent girls: a systematic review. *Health Education Research*, 2011;26(6):1025–1049. https://doi.org/10.1093/her/cyr040
69. Howard. Attitudes of High School Students toward Physical Education and Their Sport Activity Preferences. *Journal of Social Sciences*, 2011;7:529–37. https://doi.org/10.3844/jssp.2011.529.537
70. Bonderup Dohn N, Situational interest of high school students who visit an aquarium. *Science Education,* 2011;95(2):337–357. https://doi.org/10.1002/sce.20425
71. Roure C, Kermarrec G, Pasco D. *How can situational interest promote learning strategies in physical education?* 12th FIEP European Congress; 2018.
72. Domville M, Watson PM, Richardson D, Graves LEF. Children's perceptions of factors that influence PE enjoyment: A qualitative investigation. *Physical Education and Sport Pedagogy*. 2019;24(3):207–219. https://doi.org/10.1080/17408989.2018.1561836
73. Roure C, Lentillon-Kaestner V, Méard J, Pasco D. Universality and Uniqueness of Students' Situational Interest in Physical Education: A Comparative Study. *Psychologica Belgica*, 2019;59:1–15. https://doi.org/10.5334/pb.446
74. Chen S, Sun H, Zhu X, Chen. Relationship between motivation and learning in physical education and after-school physical activity. *Research Quarterly for Exercise and Sport*, 2014;85(4):468–477. https://doi.org/10.1080/02701367.2014.961054
75. Min-Hau C, Phillips DA. The relationship between attitude toward physical education and leisure time exercise in high school students. *Physical Educator*, 2002;59(3):126.
76. Silverman S, Subramaniam PR. Student attitude toward physical education and physical activity: A review of measurement issues and outcomes. *Journal of Teaching in Physical Education*. 1999;19(1):97–125. https://doi.org/10.1123/jtpe.19.1.97
77. Bibik JM, Goodwin SC, Orsega-Smith EM. High school students'attıtudes toward physical education in Delaware. *Physical Educator*, 2007;64(4):192.
78. Linda Rikard G, Banville D. High school student attitudes about physical education. *Sport, Education and Society*. 2006;11(4):385–400. https://doi.org/10.1080/13573320600924882
79. Subramaniam PR, Silverman S. Middle school students' attitudes toward physical education. *Teaching and Teacher Education*, 2007;23(5):602–611. https://doi.org/10.1016/j.tate.2007.02.003
80. Chen A, Wang Y. The role of interest in physical education: A review of research evidence. *Journal of Teaching in Physical Education*, 2017;36(3):313–322. https://doi.org/10.1123/jtpe.2017-0033
81. Digelidis N, Papaioannou A, Laparidis K, Christodoulidis T. A one-year intervention in 7th grade physical education classes aiming to change motivational climate and attitudes towards exercise. *Psychology of Sport and Exercise.* 2003;4(3):195–210. https://doi.org/10.1016/S1469-0292(02)00002-X

Information about the author:

Ahmet E. Sağın; https://orcid.org/0000-0002-4243-8276; a.enesssagin@gmail.com; Health Sciences Institute, Inonu University; Malatya, Turkey.

Cite this article as:
Sağın AE. The role of gender in predicting life satisfaction of the interest in physical education lesson. *Pedagogy of Physical Culture and Sports,* 2022;26(2):83–92.
https://doi.org/10.15561/26649837.2022.0202

Received: 07.11.2021
Accepted: 27.12.2021; Published: 30.04.2022

2022
02

REVIEW ARTICLE

Criticisms and perspectives of heuristic learning in physical education

Tiziana D'Isanto[1AD], Felice Di Domenico[2BD], Sara Aliberti[2CD], Francesca D'Elia[1CE], Gaetano Raiola[2AE]

[1]*Department of Human, Philosophical and Education Sciences, University of Salerno, Fisciano, Salerno, Italy*
[2]*Department of Political and Social Studies, University of Salerno, Fisciano, Salerno, Italy*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim The ecological-dynamic approach promotes motor learning through task variability, modification of environmental constraints and appropriate use of feedback, original and creative motor solutions. This study wants to open a critical perspective on the didactics of physical activity selecting a methodological perspective adherent to ecological-dynamic approach. The aim is to highlight the significant aspects and the uniqueness and unrepeatability of heuristic learning, starting from theoretical lines.

Material and Methods For this purpose, an accurate survey of the scientific literature has been analyzed, highlighting the points of contact and contrast of cognitive and ecological-dynamic approach.

Results In the context of physical education, the most used pedagogical approach is the linear one. Teaching is influenced by spatial and temporal constraints, spaces and equipment, with reproduction styles and with predefined tasks and motor responses. This modality promotes awareness of motor skills and not transferability to other subject areas, as indicated by ministerial documents. Non-linear pedagogy, while promoting motor learning as a consequence of the interaction between the subject and the context, shows some limits. The first concerns the learning of transversal skills and, the second concerns the use of prescriptive teaching, absent in the ecological-dynamic approach, through heuristic learning.
It is necessary to overcome the areas of prescriptiveness that still resist in the paradigm most recognized by the scientific community, the Constraints Led Approach, closely related to nonlinear pedagogy. They do not favor completely a heuristic learning as the anthropometric constraints suffer from the limitation of biomechanics. Also, goal constraints are prescriptively determined by the physical education teacher, which is not compatible with heuristic learning.

Conclusions Conclusions. This analysis highlights the need, usefulness and usability of heuristic learning in different professional fields. The study aims to offer a new perspective on physical education objectives in the National Indications, projecting them towards a social and transversal purpose.

Keywords: ecological-dynamic approach, teaching method, soft skills, life skills, didactics exercise.

Introduction

The teaching-learning process, adopted by physical education teachers in Italian high schools, has been developed traditionally on models and practices signed by dualistic relationships. An example is the relationship between theory and practice, object and subject, mind and body, quantity and quality, which influence teaching styles and consequent approaches to the learning process [1]. The learning process has been suffering from causal and linear visions and prescriptive methodological-didactic frameworks. They, despite the consolidated practices and theoretical foundations supporting them, cannot comprehensively understand the complexity of the mechanisms that are established in the realization of human movement. Specifically, it concerns the complex interaction between the individual and the environment and the circular relationship between perception and action. They are understood through an ecological-dynamic approach [2]. A valid educational process, including a variety of methodological approaches and teaching styles, [2] could take into consideration the physical, psychological characteristics and needs of students to determine different ways of elaborating information. Consequently, a valid educational process would facilitate original and creative motor responses in the students [3]. Each motor learning experience should be planned, monitored, inclusive and as significant as possible. It should be developed in the curriculum from pre-school education and constitute a continuous commitment of the student in sport and physical activities. Physical education lessons should respect the individuality of each student by facilitating their interaction and collaboration to make them acquiring knowledge, skills, motor skills and transversal skills (soft and life skills). The aim is to subsequently be able to better deal with daily problems and have a better quality of life [4]. A pedagogical-didactic process requires knowledge of content and organizational methods, but also knowledge and mastery of teaching approaches

doi:10.15561/26649837.2022.0203

and teaching styles to foster the development of significant motor learning. This requires a didactical-methodological approach which triggers interactions between psychological, emotional, perceptual, coordinative, motivational factors [5, 6], taking into consideration the contextual variables. If the organizational modalities and motor tasks have their functional valence, also teaching styles have their didactic valence. They provide communication and educational relationship between teachers and students [7]. We know that there is not a teaching style better than another, but the most appropriate can be identified to develop skills and motor competences to stimulate the development of soft skills [8]. A particular teaching style should combine the need to implement disciplinary content with the characteristics and educational needs of the student. So, the teacher has the task of creating an appropriate and stimulating learning context for the optimal development of the skills and competences of the student [9]. Regarding motor learning, it emerges the need to develop theories and teaching models referable both to the cognitive and ecological-dynamic approach. We need to emphasize teacher-student relationship, human and material resources available and the environmental context of learning, where students acquire useful information to perform motor experiences [10]. It is clear that the type of approach used by the teacher has a relevant value [11] because it significantly influences how students improve their knowledge, skills and motor competencies.

Hypothesis. Highlighting the educational-formative valence and the influence of different didactic approaches on motor learning, we want to open a critical scenario on the current didactics of motor activities. We also want to tend a theoretical framework of reference of the ecological-dynamic approach, according to a dualistic scheme (prescriptive versus heuristic).

Purpose. The purpose is to highlight, starting from the theoretical lines, the methodological applications of the ecological-dynamic paradigm, highlighting the points of contact and contrast of cognitive and ecological-dynamic approach.

Material and Methods

Data sources and search strategy

An in-depth investigation of the scientific literature was conducted highlighting the main points of contact and contrast of the cognitive and ecological-dynamic approach, with the theoretical and argumentative elaboration of operational proposals. For the purpose of searching the available literature, following data bases were used: Scopus, Scholar and Web of Science. Searching was performed using following terms (individually or in combination): heuristic learning, cognitive approach, CLA, teaching method, physical education. All the papers and abstracts were evaluated for selection of potential papers to be included in the systematic overview. Relevant studies were considered after detailed search if they met the criteria.

Type of study and analysis

Inclusion criteria. Theoretical and practical studies about motor learning approaches and limitation of CLA and non-linear pedagogy were included in the analysis.

Results

Only 29 articles met the inclusion criteria and were included in two paragraphs: one on motor learning approaches and one on the limitation of CLA and non-linear pedagogy; then concluding with a comparison between the two approaches, cognitive and ecological-dynamic, through methodological proposals.

1. Motor learning approaches: conceptual and empirical definitions and comparative results

In the last years, didactic research has focused on the teaching-learning process, that is, on the transition from how the teacher teaches to how the student learns [12, 13, 14, 15]. The choice of methodological-didactical approach implies how the teacher should teach, how the pupil learns, imposing observation and evaluation of different motor tasks and response modes in qualitative and quantitative terms [16]. The approach may be cognitive and ecological-dynamic and, differently for each student, it may have different effects on learning, psycho-social development and the enhancement of individual differences [17]. The cognitive approach determines the following learning methods: by imitation and by conditioning. These are learning based on the repetition of the task with predefined and inflexible organizational and environmental methods which, due to their predictability and repetitiveness, when skills are acquired, perfected and automated. They also produce an inversely proportional effect in terms of cognitive commitment, e.g. the reduction of attention and motivation levels [18]. In this approach, the teacher determines the motor task, intensity, duration, constraints, etc. This methodological-didactical approach is the one most used at school in physical education, in which teaching is influenced by spatial and temporal constraints, spaces and equipment, with styles of reproduction and with predefined tasks and motor responses. In this sense, this modality only promotes the awareness of how motor skills are acquired and not the transferability of these motor acquisitions to other disciplinary and extra-disciplinary areas. The constraints represent a series of factors that influence learning and motor-sports performance all time, based on the relationship established with the environment [19]. The aforementioned interacting constraints are dynamic and in continuous evolution so as to alter or facilitate the activity of the student, making his behavioral adaptability stronger [20]. The scientific literature promotes an interaction between the constraints during physical-sports activity. This reciprocal influence is constant. Therefore, a student must be able to self-regulate the various constraints in order to generate effective and efficient movement solutions [21]. Otherwise, in pedagogy non-linear acquisition of knowledge, skills and motor skills occur because of the interaction between the subject and the environmental context. And the tasks become significant by promoting the appropriate links with previous learning, preparing the student for the following ones [22]. However, having some limitations regarding the learning of transversal skills (soft and life skills) and rerushing to prescriptive teaching in some stages of learning, something that the ecological-dynamic approach, through heuristic learning, does not provide at all.

The ecological-dynamic approach is phenomenological, it describes laws and principles on which the motor control system is based on [23] and has self-organizing properties. By practicing on a specific task with this approach does not mean always repeating the same solution, but repeating several times the process of solving the task itself [24]. Teaching in the heuristic-dynamic approach is aimed to stimulate the emergence of spontaneous solutions to motor problems, that is, to implement a process of finding motor solutions through the continuous variation of motor actions [25]. In heuristic learning, the teacher assists the student in the autonomous research of motor solutions, but if the learning task is too complex, the student should not be prescriptively instructed on how to simplify motor execution, and the constraints of the environment should be modified [26]. Moreover, self-regulation has a main function [27] that is, to permit the free expression of movement in interaction with others and with the limits of the context. The ecological-dynamic approach promotes, with contributions of different methodological approach rather than the cognitive one, motor learning in a heuristic form, through didactic experiences based on variability of tasks, modification of environmental constraints and appropriate use of feedback (intrinsic and extrinsic). So, students can develop original and creative self-generative and self-determined motor solutions. In this process, the teacher assumes a different role according to the approach adopted. In the presence of a cognitive approach the teacher will play his role with a function of instructor predetermining with different degrees of prescription the activities to be performed and the goals to be achieved. In the case of ecological-dynamic approach, the teacher assumes the role of observer and supporting the students in their activities of exploration and discovery [28]. Executive variability is not seen as a limiting factor, but as an index of the non-linear interaction of the system with the constraints imposed by the organism, the task and the environment in the process of finding new motor solutions [29]. The teacher proposes content and organizes the educational setting. He chooses the teaching style (of reproduction and production, guided discovery and problem solving), proposing motor tasks not always predefined [30], in which the student can experiment with the executive variants of motor skills (e.g. playing 3vs3 in mini-basketball or mini-volleyball). Through productive styles, guided discovery, and problem-solving, the pedagogical-didactic focus is placed on the learner and operational proposals will need to consider the complex interactions that occur between students, the task, and environmental constraints [31]. On the other hand, through reproductive styles, the focus is placed on the teacher, promoting prescriptive teaching.

2. Limitations of CLA and non-linear pedagogy

Considering the scientific evidence from different areas, in particular the theories of the ecological-dynamic paradigm and neuroscience [32, 10], it is necessary to surpass those areas of prescriptiveness that still resist, such as for anthropometric constraints, goal constraints and in the practice of sports games. For example, the use of the Constraints Led Approach (CLA), strictly related to non-linear pedagogy [33], does not completely promote heuristic learning. This is because anthropometric and goal constraints are prescriptively determined by the physical education teacher, poorly reconciled with heuristic learning, especially in educational terms. In ecological-dynamic approach, 3 different types of constraints that modify and shape the behaviors of a complex dynamical system can be identified: organic, environmental, and activity constraints. In contrast, the ecological-dynamic approach studies the activity of the complex dynamical system by leaving it to evolve independently under specific manipulations of the constraints [34]. The ecological-dynamic approach, in fact, determines specific ways of learning by discovery, by problem solving, as well as having a strong impact on intrinsic motivation and in providing fun to do this type of motor experiences. These motor experiences are determined, in the school context, also through cooperative strategies, such as circle time, cooperative learning, role playing, peer tutoring, etc. The goal is to facilitate the priority acquisition of soft and life skills, as described in the Ministerial Indications for the part related to physical education. In addition, these practices make it possible to work together to try to overcome the gap between excellent and not-excellent students in motor skills, for example, through peer tutoring, that is, a cooperative strategy that increases learning capacity, self-esteem and motivation of both the student-tutor and the student-tutee, overcoming the motor skills gap between the two groups. Prescriptive teaching, on the other hand, increases the gap, because those who are able to perform the exercises imposed by the teacher, pass to the next level, while those who need more time will continue to be unable to perform that particular motor task. It is therefore of considerable educational and social impact to be able to provide for the possibility of personalizing teaching-learning. This also provides students with Special Educational Needs to participate and learn with others [35]. Some of them may express the need for longer time to learn and to solve motor problems. It will be possible to valorize individual differences and therefore personalize the motor and sport experience only if the educational path has not been predefined by the teacher. Not surprisingly, reasonable accommodation is also mentioned in Art.2 of the UN Convention on the Rights of Persons with Disabilities, 2006 (ratified in Italy by Law 18 of March 3, 2009), that is, to be able to apply modifications and adaptations necessary to ensure that all people with disabilities enjoy all human rights and fundamental freedoms. These indications transferred to the didactics of physical education means by recognizing and designing different didactic programs to promote the learning of motor and sports skills, but especially transversal skills [36]. The foundations of this type of teaching can be traced, as previously highlighted, to the paradigm of the ecological-dynamic approach, in which an important value is attributed to the variability of the environment and the stimuli generated by it [37], to the teaching style, in which the teacher has a role as a facilitator, while the student has a role of active research and experimentation in processing data and producing answers for the resolution of motor problems. An observational study on the indirect teaching style showed that this style has a high influence on students' social development, self-perception, cooperative activities, and that it succeeds in promoting intrinsic motivation, awareness of the meanings and values of physical education [38]. Other research also moves in this direction, in which the positive impact of the play is highlighted:

- It involves all students, independently of their motor skills,

- It promotes and facilitates cooperative learning and socialization processes [39, 40].

Finally, it is hoped that physical education, starting from pre-school through the area of experience "the body and movement", in continuity with the Primary School and the Secondary School of the first degree, will be developed through didactic-motor programs that stimulate heuristic learning by promoting not only the motor development of students, but also and especially the cognitive, affective and social-relational ones (soft and life skills).

3. Methodological proposals of the two approaches compared

Table 1 shows some examples of activities to propose, underlining the difference between heuristic learning and prescriptive teaching. Regarding heuristic learning, the general scheme consists of:

- Choice of theme, also previously anticipated by the teacher.
- Brainstorming activities, a modality of teamwork used to encourage creative thinking and the production of multiple ideas, where each student expresses what they know about the chosen topic.
- Vision of a video-tutorial or scheme, prepared by the teacher, on the activity to be performed with a defined objective.
- Autonomous division of children into cooperative groups to practice. The activity can be modified through the rules and the environment. Some alterations of the environment and the rules of the game, especially for older children, could consist of reducing the height volleyball net reducing the size of the court with the aid of lighter balls in basketball and volleyball for more control, more touches, more time, more passes, more freedom.
- The teacher assesses through grids and can only help kids find the solution through clues or by asking questions. He cannot demonstrate or give the answer.
- At the end, the practice of circle time will be performed to deal with relational and emotional topics regarding the activity performed.

Regarding prescriptive teaching, the general scheme consists of:

- Choice of theme and objective to be reached by the teacher.
- Explanation and demonstration of the activity to be performed.
- Execution of the activity by the students, using partial exercises (simplified, segmented), varied, randomized, error correction.

To sum up, prescriptive teaching with the use of didactic exercises enhances physical performance and skill refinement, little autonomy, much external independence, high specialization, low flexibility, preordained and repetitive patterns, and maximum development of conditional skills, but limited applicability in competition. Heuristic learning, on the other hand, with the use of instructional delivery promotes self-programming, self-determination, self-regulation, autonomy, high flexibility/low specialization, problem solving and creativity,

Table 1. Practical examples of some activities divided by each thematic core for prescriptive teaching and heuristic learning.

Thematic core	Activity	Heuristic learning	Prescriptive teaching
The body and the relationship with space and time	Path, circuit	Brainstorming on motor schemes and watching a video, with subsequent discussion. The teacher prepares a circuit based on the discussion that emerged, but does not explain how to perform it: he/she leaves the students free to explore. He/she can intervene through questions or by applying the degrees of freedom. Circle time.	The teacher explains and demonstrates how to perform the paths or circuits. Children imitate the teacher's actions.
Body language as a communicative-expressive modality	Nature imitation	After watching and discussing a video on nature, the students will have to assume the various positions of characters/objects of nature in free interpretation, chosen by their classmates in turn. Circle time.	Perform the positions of the teacher demonstrating various positions of characters/objects of nature.
The game, sport, rules and fair play	Fair play and rules in sport	Brainstorming on what the students mean by fair play, dividing them into groups. Watching a video on some examples. Discussion about what has been seen and application of the rules through a sport. Circle time.	Teacher explains what fair play means, explaining a sport game with its rules.
Health wellness prevention and safety	Path at various levels of difficulty.	Brainstorming on risk prevention and perception and watching a video on this focus, with discussion. Have the students construct a route with various options, placed side by side, so that everyone can choose which one based on their perceptions of their own difficulties and potential. Circle time.	The teacher prepares a course at various levels of difficulty, explaining how to perform it.

minimal development of conditional skills, but high applicability in competition. In this view, remembering that physical education must be of quality and quantity, able to influence all four domains of the person, such as physical efficiency, motor coordination, executive functions and life and soft skills, we can summarize by stating that the teaching-learning method that best lends itself to the achievement of these objectives is the heuristic one.

Discussion

Physical Education is a discipline that can make a specific contribution to the development of different domains of human functioning, thanks to the constant activation and mediation of the body and movement by promoting within the school curriculum:

The development of motor potential, starting with basic motor patterns, and then evolving into specific skills, including technical, sporting and expressive skills);

The development of social-relational skills through recreational-sport activities, rules and fair play;

The development of active and healthy lifestyles for the maintenance of an adequate level of psycho-physical well-being (as a fundamental element of health and prevention).

Physical education is characterized, therefore, as a discipline of "hinge" between the scientific field (knowledge of the body, how it works, movement), expressive communication, relationship and citizenship [41]. These aspects are punctually considered in the 2012 Directions. The study wants to open a new scenario on the use of the ecological-dynamic approach in teaching practices through the method of heuristic learning, which has a peculiar feature by developing a unique and unrepeatable way for each individual with executive particularities that take into account the structural anthropometric characteristics and different cognitive functions. Moreover, by not receiving any indication during the motor-sport experience from external subjects (e.g., teacher or coach), it is the self-regulation the main function and allows the free expression of movements in interaction with others and with the limits of the context. The teacher has the task of facilitating activities, stimulating spontaneous solutions to respond to problems that arise, ensuring safety and developing the maximum motor potential for everyone. The need to move towards the structuring of dynamic ecological teaching methodologies has emerged, such as laboratories that, through heuristic learning, promote the construction of learning by the student, which corresponds to a non-directive teaching where the student takes on different functions of the teacher, differentiating into teaching and tutoring among peers, small group and cooperative learning, and self-learning; such outcome is what does not happen in the cognitive approach and what, on the contrary, happens only partially in the ecological-dynamic one.

Conclusions

The study wants to offer a new perspective on the objectives of physical education in the National Indications, which already present a heuristic profile because they are not performance objectives, but project learning towards transversal and socialization objectives. In the light of what has been analyzed and exposed, the articulation of disciplinary purposes should be divided into intrinsic, extrinsic and the whole teaching-learning process needs intentionality and systematicity in the different didactic phases. Ascertained that the different methodological approaches produce different effects on the ways of learning and that an approach with reproductive styles is not the optimal solution for the quality of learning to respect individuality, enhance the capabilities of individuals and include all students. Therefore, it is necessary to ensure and propose motor experiences through production styles capable of bringing out original and multivariate motor skills, and furthermore, these skills would have a higher frequency of being transferred to other areas. It is necessary to remember that the process of meaningful learning [42] and the proximal development of it [43] and the production of learners' motor skills are continuously influenced by the constraints due to the interaction between individual-activity-environment. This interaction, alongside the active role of the learner and the facilitating role of the coach (teaching style/ learning by discovery), produces significant changes in the learning processes and in the motor and sport responses of the learners by assigning a primary role to heuristic learning in the pedagogical-didactic domain.

References

1. Aartun I, Walseth K, Standal ǾF, Kirk D. Pedagogies of embodiment in physical education: a literature review. *Sport Educ Soc*. 2022;27(1): 1–13. https://doi.org/10.1080/13573322.2020.1821182
2. Raiola G, Di Domenico F. (. Approaches to motor learning. Cognitive approach versus ecological dynamic one. *J. Hum. Sport Exerc.* 2021; 16(3): 1491–1505. https://doi.org/10.14198/jhse.2021.16.Proc3.65
3. Chow JY. Nonlinear learning underpinning pedagogy: Evidence, challenges, and implications. *Quest*. 2013;65(4):469–84. https://doi.org/10.1080/00336297.2013.807746
4. D'Isanto T, Manna A, Altavilla G. Health and physical activity. Sport Science. 2017;10(1): 100–105.
5. Altavilla G, Furino F, Marika DP, Raiola G. Physical skills, sport learning and socio-affective education. *Sport Science,* 2015;8(1): 44–46.
6. D'Elia F, Izzo R, Senatore B. Self-physical and emotional perception in rhythmic gymnastics for drop out. *J. Hum. Sport Exerc.* 2019;14(4): 1071–1079. https://doi.org/10.14198/jhse.2019.14.Proc4.70
7. Byra M. Teaching Spectrum-Style-Part 1. Runner. *The Journal of the Health and Physical Education,* 2018; 49(1): 24–31.
8. Invernizzi PL, Crotti M, Bosio A, Cavaggioni L, Alberti G, Scurati R. Multi-Teaching Styles Approach and Active Reflection: Effectiveness in Improving Fitness Level, Motor Competence, Enjoyment, Amount of Physical Activity, and Effects on the Perception of Physical Education Lessons in Primary School Children. *Sustainability*. 2019;11(2): 405. https://doi.org/10.3390/su11020405
9. D'Elia F. Teachers' perspectives about contents and learning aim of physical education in Italian primary school. J. Hum. Sport Exerc. 2020;15(2): 279–288. https://doi.org/10.14198/jhse.2020.15.Proc2.19
10. Bortoli L, Robazza C. L'apprendimento delle abilità motorie. Due approcci tra confronto ed integrazione [Learning of motor skills. Two approaches between comparison and integration]. *SdS-Rivista di Cultura Sportive,* 2016;109:24–34.
11. Altavilla G, Di Tore PA. Physical education during the first school cycle: a brief social psycho-pedagogical summary. *J. Phys. Educ. Sport*. 2016;16(2): 340–344.
12. Frabboni F, Baldacci M. *La qualità della didattica nella scuola che cambia* [The quality of the didactics in the school that changed]. Franco Angeli, Milano; 2001.
13. Calvani A. *«Decision Making» nell'istruzione.«Evidence Based Education» e conoscenze sfidanti*. ["Decision Making" in education. "Evidence Based Education" and challenging knowledge.]. *J. Educ. Cult. Psychol. Stud*. 2011;2(3): 77–99.
14. Myer GD, Faigenbaum AD, Edwards NM, Clark JF, Best TM, Sallis RE. Sixty minutes of what? A developing brain perspective for activating children with an integrative exercise approach. Br. J. Sports Med. 2015;49(23), 1510–1516. https://doi.org/10.1136/bjsports-2014-093661
15. Moy B, Renshaw I, Davids K. The impact of nonlinear pedagogy on physical education teacher education students' intrinsic motivation. *Phys Educ Sport Pedagogy*. 2016;21(5): 517–538. https://doi.org/10.1080/17408989.2015.1072506
16. Ceciliani A. Multilateralità estensiva e intensiva,

una necessaria integrazione in educazione fisica nella scuola primaria. [Extensive and intensive multilateralism, a necessary integration in physical education in primary school]. *Formazione & Insegnamento*. 2016;14(1): 171–187.
17. . Chow JY, Atencio M. Complex and nonlinear pedagogy and the implications for physical education. *Sport Educ Soc.* 2014;19(8): 1034– 1054. https://doi.org/10.1080/13573322.2012.728528
18. Raiola G. Motor learning and teaching method. *J. Phys. Educ. Sport*. 2017;17(5): 2239–2243.
19. Davids K, Button C, Bennett S. *Dynamics of skill acquisition: A constraints-led approach*. Human Kinetics; 2008.
20. Araujo D, Davids K, Hristovski R. The ecological dynamics of decision making in sport. *Psychol. Sport Exerc.* 2006;7: 653–676. https://doi.org/10.1016/j.psychsport.2006.07.002
21. Renshaw I, Chow JY, Davids K, Hammond J. A constraints-led perspective to understanding skill acquisition and game play: A basis for integration of motor learning theory and physical education praxis? *Phys Educ Sport Pedagogy* . 2010;15(2): 117–137. https://doi.org/10.1080/17408980902791586
22. Chow JY, Davids K, Button C, Shuttleworth R, Renshaw I, Araújo D. The Role of Nonlinear Pedagogy in Physical Education. *Rev. Educ. Res.* 2007;77(3): 251–278. https://doi.org/10.3102/003465430305615
23. Raiola G. Motor control and learning skills according to cognitive and ecological dynamic approach in a vision on behaviorism, cognitive, Gestalt and phenomenology theories. *Mediterr. J. Soc. Sci.* 2014; 5(15): 504–506. https://doi.org/10.5901/mjss.2014.v5n15p504
24. Hastie P, Siedentop D. An Ecological Perspective on Physical Education. *Eur. Phys. Educ. Rev.* 1999;5(1): 9–30. https://doi.org/10.1177/1356336X990051002
25. Dhawale AK, Smith MA, Ölveczky BP. The role of variability in motor learning. *Annu. Rev. Neurosci.* 2017;40(1): 479–498. https://doi.org/10.1146/annurev-neuro-072116-031548
26. Renshaw I, Chow JY. A constraint-led approach to sport and physical education pedagogy. *Phys Educ Sport Pedagogy*. 2019;24(2):103–116. https://doi.org/10.1080/17408989.2018.1552676
27. Kelso JAS. *Dynamic patterns: The self-organization of brain and behavior*. The MIT Press; 1995.
28. Sannicandro I. Ecological dynamics approach in the youth soccer: A short narrative review. *J. Hum. Sport Exerc*. 2020; 15(4): 1133–1139. https://doi.org/10.14198/jhse.2020.15.Proc4.14
29. Slifkin AB, Newell KM. Is Variability in Human Performance a Reflection of System Noise? *Curr Dir Psychol Sci.* 1998; 7(6): 170–177. https://doi.org/10.1111/1467-8721.ep10836906
30. Hristovski R, Davids K, Passos P, Araujo D. Sport performance as a domain of creative problem solving for self-organizing performer-environment systems. *Open Sports Sci. J.* 2012; 5(1): 26–35. https://doi.org/10.2174/1875399X01205010026
31. Tan CWK, Chow JY, Davids K. 'How does TGfU work?': examining the relationship between learning design in TGfU and a nonlinear pedagogy. *Phys Educ Sport Pedagogy*. 2012; 17(4): 331–348. https://doi.org/10.1080/17408989.2011.582486
32. Dietrich A, Haider H. A neurocognitive framework for human creative thought. *Front. Psychol*. 2017; 7: 2078. https://doi.org/10.3389/fpsyg.2016.02078
33. Chow JY, Davids K, Button C, Shuttleworth R, Renshaw I, Araújo D. Nonlinear pedagogy: A constraints-led framework to understand emergence of game play and skills. *Nonlinear Dyn. Psychol. Life Sci*. 2006; 10(1): 74–104.
34. Davids K, Araújo D, Correia V, Vilar L. How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exerc Sport Sci Rev*. 2013; 41(3): 154–161. https://doi.org/10.1097/JES.0b013e318292f3ec
35. Booth T, Ainscow M. *Index for Inclusion: Developing Learning and Participation in Schools*. Centre for Studies on Inclusive Education, United Kingdom; 2002.
36. D'Elia F, Tortella P, Sannicandro I, D'Isanto T. Design and teaching of physical education for children and youth. *J. Hum. Sport Exerc*. 2020; 15(4): 1527–1533. https://doi.org/10.14198/jhse.2020.15.Proc4.48
37. Valentini M, Guerra F, Troiano G, Federici A. Outdoor Education: corpo, apprendimento, esperienze in ambiente naturale. Formazione & Insegnamento. [Outdoor Education: body, learning, experiences in the natural environment. Training & Teaching]. *Rivista Internazionale di Scienze Dell'educazione e Della Formazione*. 2019; 17(1): 415–428.
38. Jung H, Choi E. The importance of indirect teaching behaviour and its educational effects in physical education. *Phys Educ Sport Pedagogy*. 2016; 21(2): 121–136. https://doi.org/10.1080/17408989.2014.923990
39. Bortolotti A, Ceciliani A. Cooperare per gioco. Educazione motoria e processi di socializzazione nella Scuola Primaria [Cooperate for fun. Motor education and socialization processes in Primary School]. *Ricerche di Pedagogia e Didattica*, 2010; 5(1): 1–31.
40. Pesce C, Marchetti R, Motta A, Bellucci M. *Joy of moving. Movimenti e immaginazione* [Joy of moving. Movements and imagination]. Giocare con la variabilit**à** per promuovere lo sviluppo motorio, cognitive e del Cittadino; 2015.
41. Altavilla G. Educational operation in relation to teaching methods in physical education. *Giornale Italiano di Educazione alla Salute, Sport e Didattica Inclusiva*, 2021; 5(1). https://doi.org/10.32043/gsd.v5i1_sup.395
42. Ausubel DP. *Educational psychology. A cognitive view*. New York: Holt, Rinehart and Winston, Inc; 1968.
43. Vygotsky LS. Thinking and speech. *The collected works of LS Vygotsky*, 1987; 1: 39–285.

Information about the authors:

Tiziana D'Isanto; https://orcid.org/0000-0001-7151-7486; tdisanto@unisa.it; Department of Human, Philosophical and Education Sciences, University of Salerno; Fisciano, Salerno, Italy.

Felice Di Domenico; https://orcid.org/0000-0002-5897-9704; fdidomenico@unisa.it; Department of Political and Social Studies, University of Salerno; Fisciano, Salerno, Italy.

Sara Aliberti; (Corresponding author); https://orcid.org/0000-0002-2470-4032; s.aliberti17@studenti.unisa.it; Department of Political and Social Studies, University of Salerno; Fisciano, Salerno, Italy.

Francesca D'Elia; https://orcid.org/0000-0003-1441-8101; fdelia@unisa.it; Department of Human, Philosophical and Education Sciences, University of Salerno; Fisciano, Salerno, Italy.

Gaetano Raiola; https://orcid.org/0000-0002-7659-1674; graiola@unisa.it; Department of Political and Social Studies, University of Salerno; Fisciano, Salerno, Italy.

Cite this article as:
D'Isanto T, Di Domenico F, Aliberti S, D'Elia F, Raiola G. Criticisms and perspectives of heuristic learning in physical education. *Pedagogy of Physical Culture and Sports,* 2022;26(2):93–100.
https://doi.org/10.15561/26649837.2022.0203

Received: 11.02.2022
Accepted: 22.03.2022; Published: 30.04.2022

2022
02

ORIGINAL ARTICLE

Comparison between determination of second anaerobic threshold by respiratory compensating point and X-method in rowers

Lachezar G. Stefanov[ABCDE]
Sofia National Academy, Bulgaria

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim The aim of this study is to verify the X-method for determining the second anaerobic threshold in rowers.

Material and Methods Twelve male athletes from the national rowing team of Bulgaria were tested. Participants performed a one-time graded incremental exercise test to exhaustion on a rowing ergometer. The workload were conducted on rowing ergometer system Concept 2, and spirometry system Clark C5. We obtained ventilatory indices, intensity and heart rate bred-by-bred for each participant, for each test stage. The anaerobic threshold was determined by two methods: 1) by the localization of the respiratory compensation point visually, after polynomial regression analysis of the trends for the dynamics of the ventilatory variables related to time and 2) by the X-method using the change in the ratio between heart rate and pulmonary ventilation. We compared the heart rate corresponding to the anaerobic threshold determined by both methods.

Results We found similar values for heart rate at the respiratory compensation point and the anaerobic threshold determined by the X-method for each of the investigated. The Shapiro-Wilk test showed a normal distribution of the two samples with a significance level of $\alpha = 0.05$. Thus, the t-test for two paired samples showed a p-value of 0.202 at $\alpha = 0.05$. We found a correlation coefficient $r = 0.973$ between the heart rate at the anaerobic threshold (determined by X-method) and the heart rate at the anaerobic threshold (detected at the respiratory compensation point). The Blant-Altman analysis showed that 95% of the points in the scatter plot lie within the confidence interval.

Conclusions The two methods give similar results and can be applied alternatively in the investigation of rowers in the age group 18.3 ± 1.07 years. The X-method always gives a reliable intersection point, which in our studies is close to the second anaerobic threshold. Comparative studies are also needed in other contingents for the wider use of the X-method.

Keywords: ventilatory threshold, heart rate, anaerobic threshold, pulmonary ventilation, endurance, non-invasive

Introduction

After proposing the concept of anaerobic threshold (AnT) and its importance for planning the training process, scientists and coaches are trying to find a way to determine it that is easy to applicable, non-invasive, accurate enough for practice, reliable and inexpensive. The large number of proposed methods can be conditionally grouped according to certain criteria.

Most of the methods are related to determining the blood lactate concentration during and after exercise. They are performed by taking a blood sample, usually from the ear pendant, i.e. invasive. Although these methods are considered the "gold standard" in determining AnT, a number of methodological problems have been described in their use [1]. Furthermore, many authors dispute the direct link between anaerobic metabolism in muscle cells and blood lactate levels [2, 3]. The fact that these methods are invasive makes them less preferred by sports professionals.

Another part of the methods for determining AnT requires expensive spiroergometric equipment and laboratory conditions described in the second half of the last century [4, 5]. They determine AnT based on ventilatory parameters, such as volume of oxygen consumption (VO_2); volume of expired carbon dioxide (VCO_2); pulmonary ventilation (Ve); ventilatory equivalent of oxygen (Ve/VO_2); ventilatory equivalent of carbon dioxide (Ve/VCO_2); end-tidal partial pressures for oxygen ($P_{ET}O_{2)}$; end-tidal partial pressures for carbon dioxide ($P_{ET}CO_{2)}$; respiratory exchange ratio (RER) [6, 7]. The analysis of the ventilatory variables shows two inflection points, of which the first, called the first ventilatory threshold (VT1) shows the upper boundary between moderate and high intensity, while the second, called the second ventilatory threshold (VT2) shows the upper boundary between high and severe intensity. VT2 is thought to be associated with respiratory compensation point (RCP) in increasing metabolic acidosis [8]. On the other hand, the lactate threshold (LT) corresponds to VT1. Some authors define this lactate threshold as the first lactate threshold (LT1). The second lactate threshold (LT2)

doi:10.15561/26649837.2022.0204

is associated with VT2 [9]. Other studies have linked VT2 to a RER of 1.00. Long known that "additional" CO_2 is released above this point as a product of the bicarbonate buffering system associated with lactate accumulation [10].

In principle, the anaerobic threshold is determined during an incremental exercise test to exhaustion by changes in ventilatory variables and / or blood lactate concentration. VT2 is determined non-invasively and seems to be an applicable training indicator and a key performance factor in endurance sports [11]. Usually AnT is compared with: the power of the work performed (W); the speed to cover a certain distance (V); the time against which the load is applied (t); and HR heart rate at the various stages of the test. The common between the different approaches is that they use incremental exercise test to exhaustion.

Maximum lactate steady state (MLSS) is another protocol and is considered the most accurate in determining AnT [12]. MLSS and critical power (CP) are two widely used indicators of higher oxidative metabolism that can be maintained under prolonged exercise and are often considered synonymous [13]. There is unarguable evidence that MLSS is specific to each sport. Furthermore, it has been accepted for at least 2 decades that although the speed at MLSS is an inarguable predictor of running endurance in a large group of runners, it also has a high risk of both overestimation and underestimation of performance [2]. Apart from the fact that the method is invasive, the procedure for its implementation requires the most time from the known methods for determination of AnT.

In the present study we analyze the upcoming changes in the observed variables according to the 3-phase model of Skinner and McLellan [14]. These authors, attempted to explain each stage of 3-phase double breakaway model and the physiological mechanisms underlying the events which occurred. These authors described the initial phase as being predominantly aerobic with a heavy reliance of type I muscle fibers and free fatty acids as the metabolic substrate. The aerobic threshold leads into the aerobic-anaerobic transition phase, which involves the recruitment of type IIa (FOG) fibers and the appearance of lactate in the blood. Lactic acid in turn decreases blood and intracellular pH and causes an increase in excess CO_2, ventilation (Ve) and RER, and a disproportionate increase in Ve/VO_2. The aerobic-anaerobic transition phase ends at the anaerobic threshold where lactate production equals its removal capacity. The anaerobic phase, the third phase follows. This phase involves the recruitment of type IIb (FG) fibers with a rapid rise in lactic acid production. Lactate production exceeds its removal with a rapid increase in blood lactate and Ve, and a decrease in the fractional concentration of expired O_2 [9].

Over the years, a number of methods have been developed to determine AnT avoiding invasive procedures and expensive spiroergometric equipment. Various strategies have been proposed, some based on responses to Ve or respiratory rate [8], while others are based on changes in HR or HR variability, all expressed as a function of time or load intensity [15]. One group of them uses changes in HR [16]. This method has caused great controversy over the years about its validity, repeatability and physiological validity. However, many coaches, especially in track and field, still use it today.

Recent studies suggest that determination the second anaerobic threshold (AT2) based on heart rate variability (HRV) during exercise may be a cheaper and non-invasive method [17, 18]. However, detailed validation studies are still lacking.

Iban Latasa [19] investigate the reliability of the surface electromyogram (EMG) for automatic detection of aerobic and anaerobic thresholds during a cycle ergometric test with increasing intensity (25 W / min) to exhaustion. They present an agreement between the first EMG threshold and VT1, on the one hand, and between the second EMG threshold and VT2, on the other, and define the method as valid and non-invasive [19]. There is still a lack of detailed research on different contingents in different sports.

Onorati et al. [15] used regression of Ve versus HR and RR (respiratory rate) versus HR. They obtain a bilinear response with a clear breakpoint of the curve. The breakpoint corresponds to the RCP determined by the standard technique with segmented regression of Ve versus VCO_2 and the ventilatory equivalents Ve/VO_2 and Ve/VCO_2 [20, 21].

Other exotic methods for determining AnT have been described, which have not been established in sports science, so I will not comment on them.

The determination of AnT by a method recently described by us [22] was compared with the AnT determined by two reference methods using blood lactate concentration. The method uses the intersection between difference (Diff) between the percentages of the %HR versus HR_{peak} and the %Ve versus Ve_{peak} on the one hand and the %Ve on the other to determine AnT. We called this method the X-method and so we will present it in the present study.

Hypothesis: After proving in a previous study [22] that there is a 95% of agreement between HR at AnT determined by the X-method, the modified D_{max} method and at fixed blood lactate concentration of 4 mmol/L, we assumed that a similar agreement there should be between X-method and VT2 determined by RCP.

The aim of this study was to verify the X-method for determination of AnT by comparing it with AnT determined by the ventilatory variables measured during the incremental maximum test in rowers.

Material and Methods

Participants.

Twelve male athletes from the national rowing team of Bulgaria were tested. Subjects admitted in the study were currently active in competition. Participants performed a one-time incremental maximum test to exhaustion on a rowing ergometer. This represents a control test for the effectiveness of the training process of the competitors from the national rowing team. The measurement procedures and potential risks were verbally explained to each subject prior to obtaining a written declaration of consent. Subject characteristics are presented in table 1.

Table 1. Subject characteristics.

Characteristics	Mean±Sd
Age (yrs)	18.3±1.07
Weight (kg)	186.7±6.54
Height (cm)	84.9±8.92
BMI	24.3±1.73

Procedure.

At the beginning of the examination, the anthropometric variables of the participants were measured and they were acquainted with the possible disadvantageous consequences of performing the test for them. Then they were familiarized with the conditions and equipment for the study. For determination of AnT, in this test we used the measurements for power (W), HR, Ve, VO_2, VCO_2, Ve/VO_2, Ve/VCO_2 and RER. Measurements were performed bred-by-bred and averaged every 30 s during the test. We used these measurements to determine the RCP. Each measurement was denoted by "t", i.e. each unit "t" represents a period of 30 s. The workload were conducted on rowing ergometer system Concept 2, spirometry system Clark C5. The initial workload was 60 W. Each stage lasted 2 minutes. Each subsequent stage was 40 W higher than the previous. Thus, we obtained measurements for each participant for HR, Ve, W, VO_2, and VCO_2 of each stage. We used these measurements to determine the AnT by X-method.

Determination of AnT by RCP

To determine AnT by detecting of RCP, i.e. VT2, we used visual methods, after polynomial regression analysis of trends in the dynamics of ventilatory variables: Ve, VCO_2, VO_2, values of Ve/VCO_2, Ve/VO_2, and RER versus time [23, 24]. According to Beaver et al. [23] RCP cannot always be detected, which is also confirmed by the experience of Ekkekakis et al. [25]. Therefore, we used a complex of several approaches to identify RCP and searched for similarities in the variables between them. To illustrate the methodology for determining AnT, we present an analysis of the measurements for one of the participants. We used the following approach to determine the RCP in the several steps:

Step 1. We describe regression for VCO_2 on the abscissa and Ve on the ordinate with a 6-order polynomial. Visually determine where the linear part of the polynomial starts after half of the course of the described curve. At the point where the linear part of the curve begins, a change in the slope of the polynomial is detected (Figure 1). We find out what value for VCO_2 corresponds to this inflection point. We record the value for VCO_2. In case such an inflection point is not detected, go to step 2.

Step 2. We describe the regression for VCO_2 in the ordinate versus time "t" on the abscissa, which corresponds to the consecutive number of the measurement. We describe a polynomial of 6-order and find the sequence number of the measurement denoted by "t" corresponding to the inflection point for Ve from step 1. This point usually coincides with the beginning of the increase in the slope of the curve (Figure 1) and we assign it as RCP.

Step 3. Regression for Ve versus "t" on the abscissa is described by a polynomial of 6-order and we look for the last linear segment in the second half of the test. At the beginning of this segment Ve begins a steeper rise (fig.1). According to the corresponding measurement number "t" we determine the achievement of RCP.

Step 4. We describe the regression for Ve/VCO_2 and Ve/VO_2 in the ordinate versus time on the abscissa expressed as "t". We determine when the course of the Ve/VCO_2 curve decreases and achieve the lowest value, followed by an increase, and we compare it with the course of the Ve/VO_2 curve, which initially decreases, followed by an increase, which at one point becomes steeper (Figure 2) [23, 26]. For this corresponding number of "t" we determine the RCP.

Step 5. We describe a regression for RER versus "t" and determine at which measurement number its value remains permanently above 1.00 (Figure 2). At this point we determine the RCP [10].

Step 6. We compare the measurement numbers corresponding to the RCP obtained in steps 2, 3,4 and 5. In case of discrepancy in the time to reach the RCP, we analyze the adequacy of the determinations in the mentioned steps and select the appropriate "t". We find HR in the corresponding measurement "t". We average the measured HR with that of the previous and subsequent measurements. This HR corresponds to the AnT determined by RCP. We compare it with the HR achieved in AnT determined by the X-method.

Determination of AnT by X-method

For determination of AnT by the X-method, we used the peak heart rate (HR_{peak}) of each participant to calculate the percentage of HR achieved (%HR)

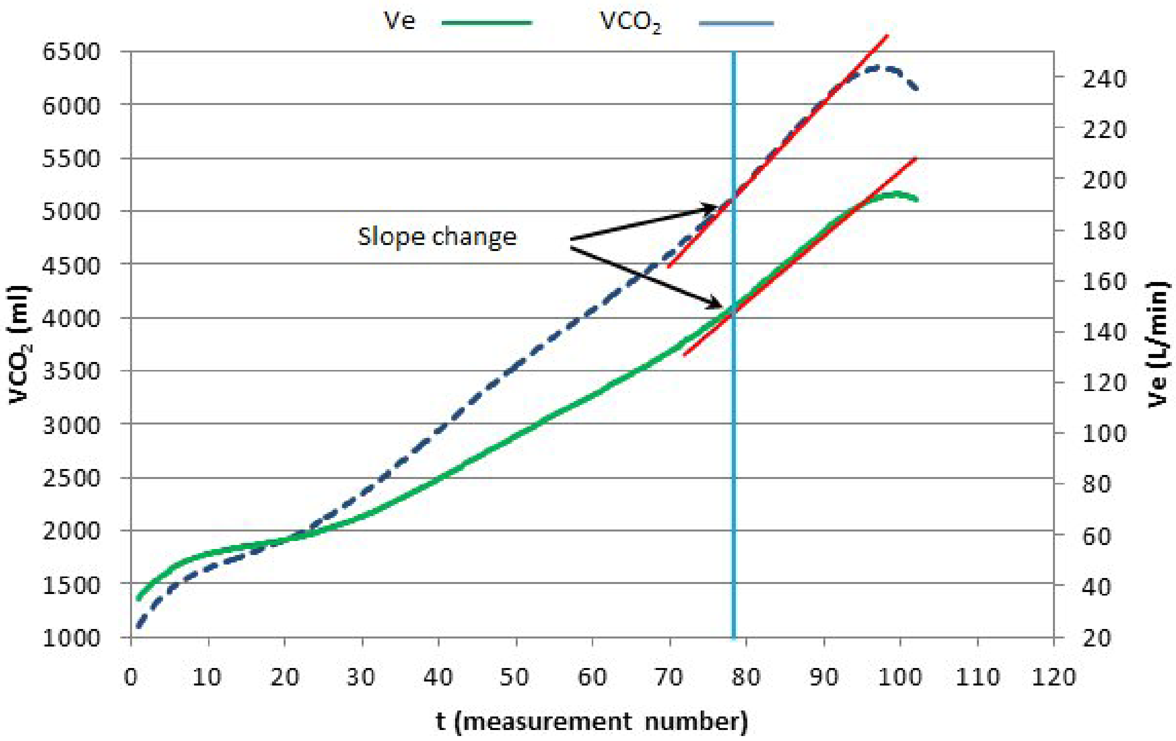


Figure 1. Represent the trends of the regression curves of 6-order polynomials for Ve and VCO2 versus t. The red, straight lines reflect the last linear segments of the two curves.

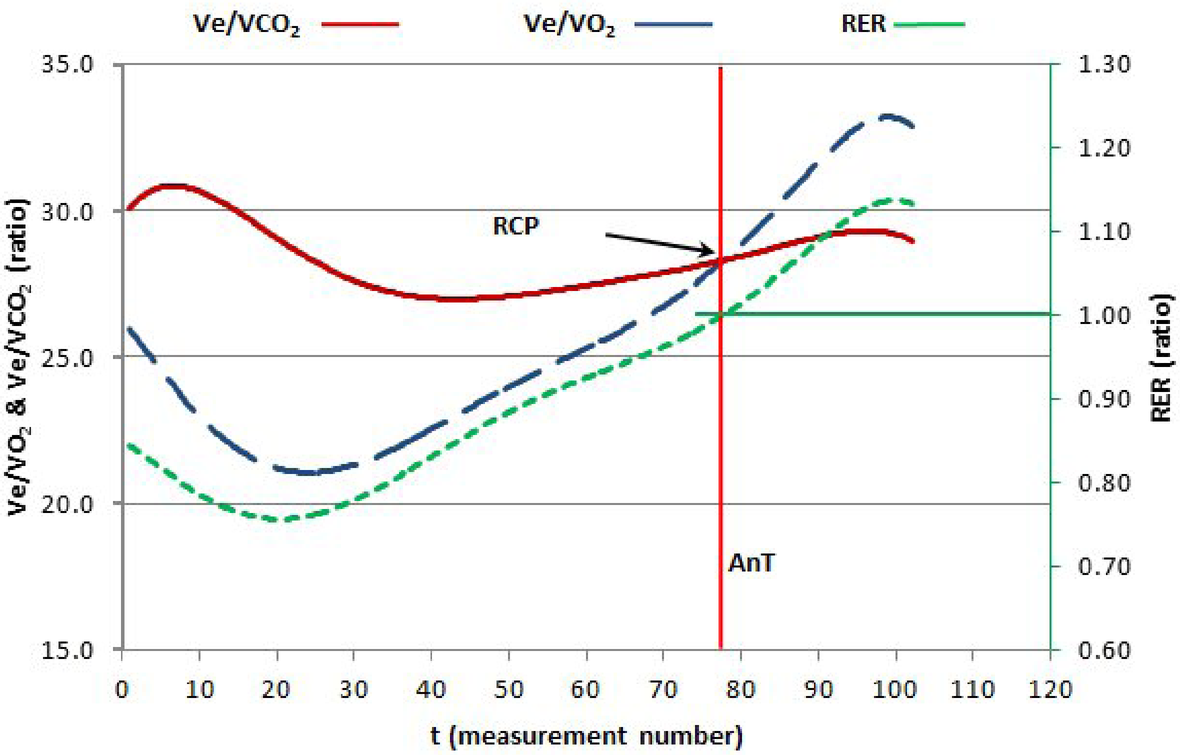


Figure 2. Represent the trends of the regression curves of 6-order polynomials for Ve/VO2, Ve/VCO2 and RER versus t. The red line indicates the RCP determined by the criteria described in steps 4 and 5, and t to which it corresponds. The green line indicates the RER corresponding to 1.00. AnT shows the measurement number corresponding to the anaerobic threshold

for each stage. Thus, we converted the absolute values for HR into percentages. We used the same procedure for pulmonary ventilation as the peak value (Ve_{peak}) was accepted as 100% of (% Ve). The approach we propose is graphical and the determination of AnT was done in a specific sequence. The difference (Diff) between the percentages of %HR and %Ve is compared with %Ve. The %Ve showed larger and more characteristic changes, and a steeper increase after a certain exercise intensity. As the exercise intensity increases, the difference in the relative proportions of the functions of the cardiovascular and respiratory systems decreases. Diff decreases while %Ve increases. This is expressed graphically by the intersection between the Diff and %Ve curves (Figure 3). This intersection point indicates AnT. The X-method uses averaged measurements for each exercise stage.

We then plot a regression between W and HR, which is described by a 3-order polynomial. We determine HR against the W detected by the X-method (Figure 4). Thus we find the HR achieved at AnT.

Statistical analysis

We first performed a variation analysis to determine the means, minimum, maximum, STDEV and coefficient of variation. The Shapiro-Wilk test showed a normal distribution of the two samples at a significance level of α = 0.05, which allowed us to use parametric methods for statistical analysis. To compare the samples of the two methods we used t-test for two paired samples at α = 0.05. To compare the two methods studied, we used Pearson's correlation coefficient. We plotted the scattering diagram of the HR obtained using both methods for determining AnT. We then used the Blant-Altman (B&A) graphical method to prove the similarity between the two compared methods at a 95% confidence interval. We used the Shapiro-Wilk test to prove a normal distribution of the differences between the two methods, which is a condition for the correct application of the B&A analysis.

For statistical data processing we used EXCEL 10 of Microsoft Office 10 and the XLSTAT application developed for the purpose.

Results

Table 2 presents the HR for AnT determined by X-method and for AnT determined by RCP for each of the participants. In the same table, the last two columns present "averages" and "differences" from (B&A) analysis, which we will discuss below.

On the table 2 they make an impression the quite close values of HR at RCP and AnT found by the X-method for each of the participants.

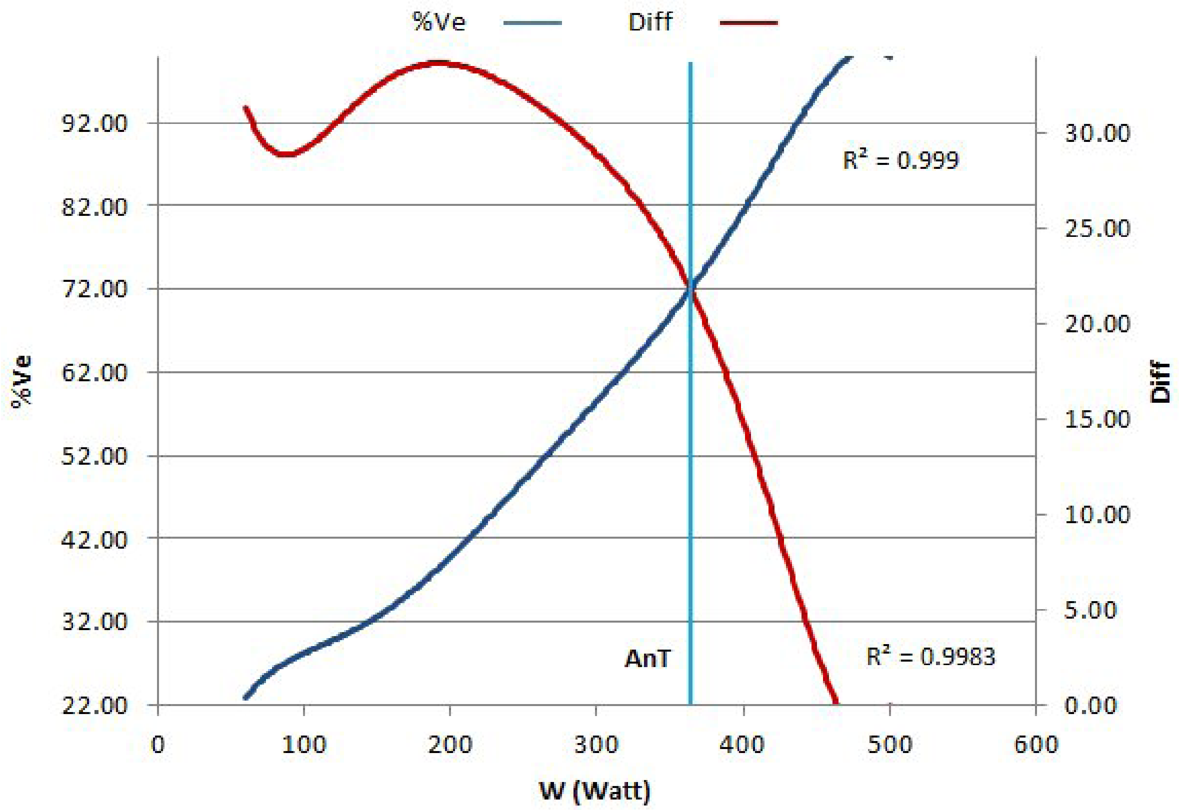


Figure 3. Represents the intersection of the curves for %Ve and Diff versus W, which corresponds to AnT. The blue line connects exercise intensity to the point of intersection.

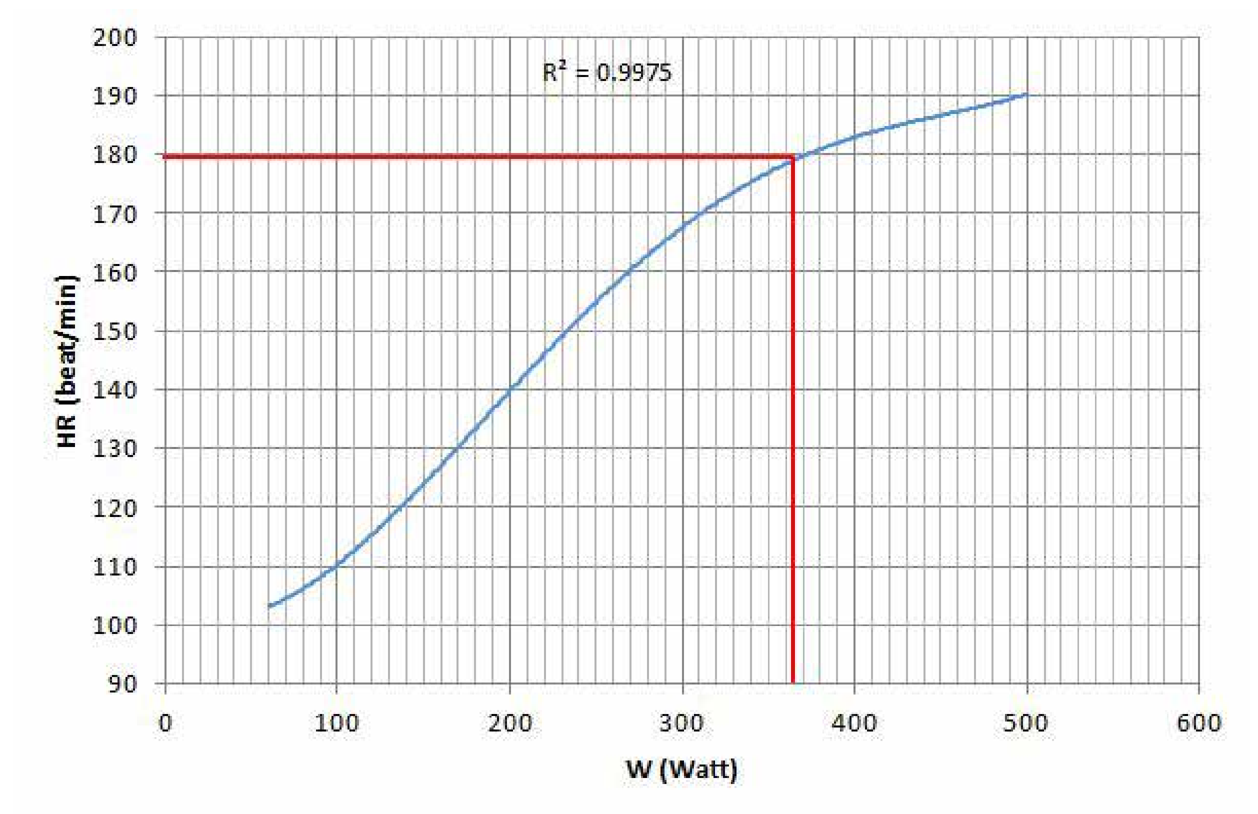


Figure 4. Reflects the ratio of HR to W. The intersection between the HR curve and the red lines determines the AnT in this case.

Table 2. Reflects the HR of each of the participants found for AnT determined by RCP and AnT determined by X-method. Presents averages and differences from B&A analysis.

Subject	HR at AT		Averages and differences from B&A analysis	
	HR at RCP	HR at X-method	Aver. (RCP + X)/2	Diff. (X - RCP)
A.N.	179	177	178.000	-2.000
N.J.	177	178	177.500	1.000
S.H.	177	175	176.000	-2.000
M.S.	184	185	184.500	1.000
N.P.	195	192	193.500	-3.000
R.K.	179	179	179.000	0.000
B.Y.	159	159	159.000	0.000
V.S.	178	175	176.500	-3.000
I.J.	184	183	183.500	-1.000
H.N.	181	184	182.500	3.000
C.M.	173	173	173.000	0.000
I.Y.	182	179	180.500	-3.000

The differences in the pairs of values between participants are bigger. In both approaches for determining AnT, the minimum and maximum values are similar, as can be seen from table 3, as the coefficient of variation (Var.) present a great homogeneity of the two samples. Dispersion (Std. Dev.) is similar for both samples, indicating that both approaches give similar results for HR.

Table 3. Presents descriptive statistics of variables for all participants.

Variable	Obs.	Min.	Max.	Mean	Std. dev.	Var.
HR at RCP	12	159	195	179	8.334	5
HR at X-method	12	159	192	178.25	8.047	5

The Shapiro-Wilk test showed a normal distribution of the two samples at a significance level of $\alpha = 0.05$. The value of $p = 0.119$ for HR at RCP and $p = 0.320$ for HR at X-method entitles us to use parametric statistical methods. Thus, the t-test for two paired samples showed a p-value of 0.202 at $\alpha = 0.05$, which means that there is no significant difference between the averages of the two compared methods.

To compare the results of the two methods, we first draw a scatter plot (Figure 5). The data is on both sides of the identity line (bisector), most of which is below the line. Therefore, the X-method slightly underestimates the HR achieved in AnT compared to the HR achieved in RCP.

Pearson's correlation coefficient presented a very large correlation $r = 0.973$ between HR at AnT determined by X-method and HR at AnT detected by RCP. The correlation coefficient **r** measures the strength of the relationship between two variables, but not the agreement between them. The Blant-Altman diagram describes the agreement between two quantitative measurements. It sets limits of agreement [27]. This method uses the differences between the two methods and the average between the two methods (Table 2, columns 4 and 5).

Table 4. Bland-Altman analysis

Bias	-0.75
Standard error	1.913
CI Bias (95%)	-1.965 ÷ 0.465
Confidence interval:	-4.499 ÷ 2.999

B&A recommends that 95% of the points in the scatter plot (Figure 6) lie within the confidence interval [28], which is -4,499 ÷ 2,999 in our study (Table 4), in order to assume that the two methods give similar results. An important condition for accepting this conclusion is that the distribution of the differences between the two methods is normal. Through the Shapiro-Wilk test we found that the differences between the two methods are normally distributed, which is a condition for the correct application of B&A analysis [27].

From the scatter plot shown in Figure 6 it is clear that the difference between the measurements of the two compared methods, drawn versus the average of the two measurements is in the confidence interval of 95%. Since the average of the two methods is 0.75 lower than 0, the X-method gives lower values compared to the determination of AnT by RCP.

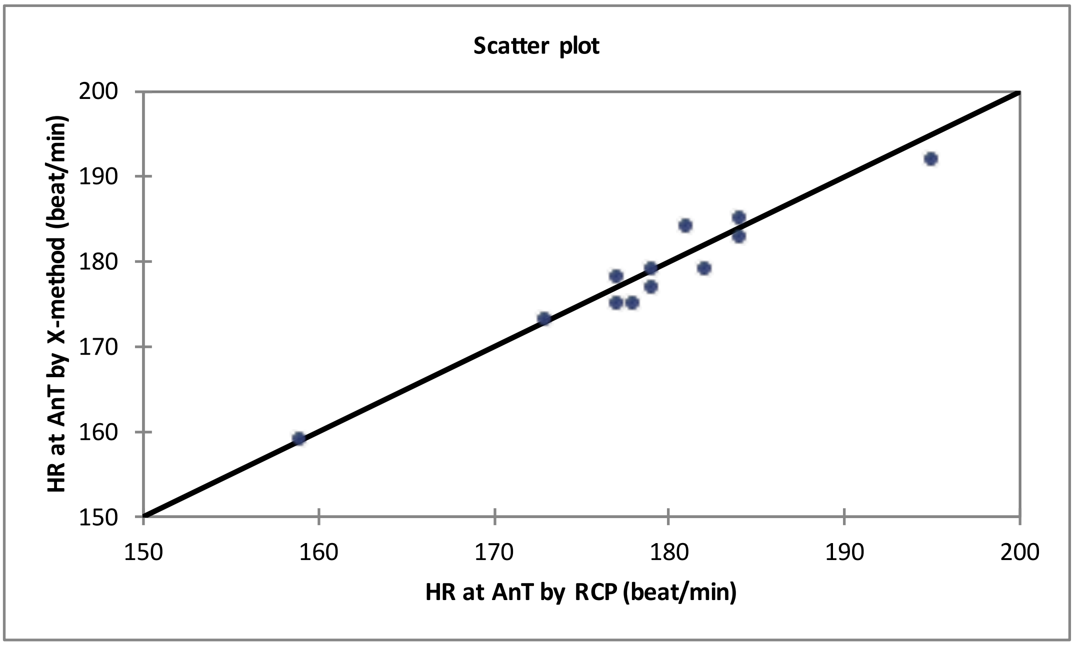


Figure 5. Scatter plot for HR measured at RCP and at AnT determined by the X-method.

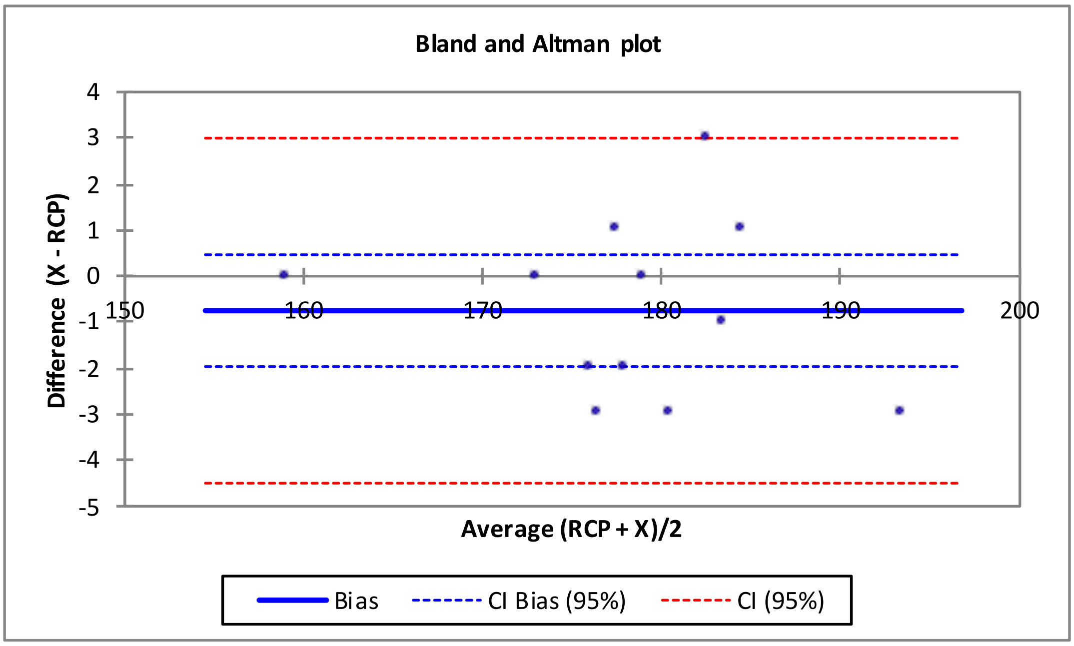


Figure 6. Diagram of Blunt-Altman analysis.

Discussion

As can be seen from the Diff curve, the difference between the function of the cardiovascular and respiratory systems decreases with increasing intensity of exercise, while %Ve increases. As the intensity of the exercise increases, the relationship between the function of the cardiovascular and respiratory systems changes. The dynamics of the heart rate is well known, at exercise with increasing to the maximum intensity, which increases linearly and close to the maximum power for the individual, this linearity is disturbed [29]. On the other hand, when the workload increases to the maximum intensity, Ve increases linearly to about 50 ÷ 75% of the maximum working capacity (W_{max}). After this point, Ve continues to rise steeper to about 85 ÷ 95% of W_{max}, where the linearity breaks again, and Ve begins to rise even steeper. The VT2 is located at this W [30]. In our study, the mean intensity at which AnT was detected, expressed as %VO2max, was 89.73% for RCP and 88.19% for X-method. The percentage of VO_{2max} in which AnT is detected, according to other authors, is similar to that found by us. Jones et al. indicate that AT2 is usually at 75-90% of VO_{2max} [13]. Laurent Bosquet [31] report that calculated thresholds using different "scientific" techniques using the same data set vary between 79 and 92% of VO_{2max}. Santos & Giannella-Neto detected RCP in 88% of VO2max [32]. Pühringer et al. detect VT2 at 83 ± 10% of VO_{2peak} [24].

The correlation coefficient between the methods we compared is r = 0.973. Ekkekakis et al. investigated the correlation between methods for determining RCP. The correlation coefficients are from 0.88 to 0.96 for computerized methods and from 0.85 to 0.97 for visual methods [25]. The indices Ve/VCO_2 and Ve used to determine RCP have a correlation coefficient r = 0.88 for automatic and r = 0.94 for visual methods [32].

From this similarity in the results it follows that in our study there are no significant errors in the methodology for determining RCP and that the X-method gives comparable results with other methods for determining AnT. The results of our study are at the upper boundary of this range, probably because the participants are athletes at national and international level. In addition to the similar %VO_{2max} in favor of the proposed method is the lower STDV of 8.047 compared to 8.334 for RCP. From a practical point of view, we can summarize that the intersection between Diff and %Ve is easy to detect and is located at about 88.4% of %VO_{2max} for the group of rowers we studied.

Ventilatory threshold measurements demonstrate significant differences between trained and untrained subjects. These differences are the result of variation in muscle mass activation, movement efficiency, or both. Another characteristic influencing the thresholds is the sex of the subjects. Differences were found between men and women for VO_{2max} and ventilatory threshold, expressed as a percentage of VO_{2max}. The type of ergometer (manual, foot or treadmill) has a significant effect on the ventilatory threshold. Activation of specific muscle groups also leads to significant differences in the ventilatory threshold [33]. Therefore, research on different sports will give different results in the determination of AnT. From this point of view, research of different contingents is needed to describe the regularities in the application of our proposed method.

Conclusions

The presented results and the performed statistical analysis show that the two methods give similar results at a correlation coefficient r = 0.973 and can be applied alternatively. In addition, the t-test for two paired samples showed a p-value of 0202 at α = 0.05, which means that there is no significant difference between the averages of the two compared methods in the study of rowers in the age group 18.3 ± 1.07 years. The determination of AnT by the X-method is more reliable, as the intersection point between the Diff and %Ve curves is easily detected graphically and its determination can be facilitated by mathematical formulas. Such automation of the method needs further development.

Acknowledgements

I would like to thank the coach of the National Rowing Team of the Republic of Bulgaria for his assistance. I would also like to thank the team from the "Laboratory for functional research" at the Directorate "Coordination and control of sports training at the "Ministry of Youth and Sports", Republic of Bulgaria.

Conflict of interest

The authors declare no conflict of interest.

References

1. Faude O, Kindermann W, Meyer T. Lactate Threshold Concepts How Valid are They? *Sports Med*. 2009; 39 (6): 469–490. https://doi.org/10.2165/00007256-200939060-00003
2. Hall MM, Rajasekaran S, Thomsen TW, Peterson AR. Lactate: Friend or Foe. *PM&R*. 2016;1: S8–S15. https://doi.org/10.1016/j.pmrj.2015.10.018
3. Ferguson BS, Rogatzki MJ, Goodwin ML, Kane DA, Rightmire LZ, Gladden B. Lactate metabolism: historical context, prior misinterpretations, and current understanding. *Eur J Appl Physiol*. 2018; 118:691–728. https://doi.org/10.1007/s00421-017-3795-6
4. HolmanW. Historical Remarks on the Development of the Aerobic-Anaerobic Threshold up to 1966. *Int. J. Sports Med*. 1985;6:109–116. https://doi.org/10.1055/s-2008-1025823
5. Mader A, Heck H. A theory of the metabolic origin of "anaerobic threshold". *Int. J. Sports Med*. 1986; 7(Suppl. 1): 45–65. https://doi.org/10.1055/s-2008-1025802
6. Wasserman K. The Anaerobic Threshold Measurement to Evaluate Exercise Performance AM. *Rev. Respir. Dis.* 1984; 129:Suppl S35–S40. https://doi.org/10.1164/arrd.1984.129.2P2.S35
7. Anderson GS, Rhodes EC. A Review of Blood Lactate and Ventilatory Methods of Detecting Transition Thresholds. *Sports Medicine*, 1989; 8(1): 43–55. https://doi.org/10.2165/00007256-198908010-00005
8. Neder JA, Stein R. A Simplified Strategy for the Estimation of the Exercise Ventilatory Thresholds *Med. Sci. Sports Exerc.* 2006;38(5): 1007–1013. https://doi.org/10.1249/01.mss.0000218141.90442.6c
9. Bindera RK, Wonischb M, Corrac U, Cohen-Solald A, Vanheese L, Sanera H, et al. Methodological approach to the first and second lactate threshold in incremental cardiopulmonary exercise testing. *Eur J Cardiovasc Prev Rehabil.* 2008; 15:726–734. https://doi.org/10.1097/HJR.0b013e328304fed4
10. Diefenthaeler F, Sakugawa RL, Dellagrana RA, Folmer B, Lemos EC, Campos W. Is respiratory exchange ratio an alternative to estimate of anaerobic threshold in trained runners. *Rev Bras Cineantropom Desempenho Hum.* 2017; 19(1):108–117. https://doi.org/10.5007/1980-0037.2017v19n1p108
11. Fabre N, Balestreri F, Pellegrini B, Schena F. The modified Dmax method is reliable to predict the second ventilatory threshold in elite cross-country skiers. *J Strength Cond Res,* 24(6): 1546–1552, 2010. https://doi.org/10.1519/JSC.0b013e3181dc450a
12. Billat VL, Sirvent P, Py G, Koralsztein J, Mercier J. The Concept of Maximal Lactate Steady State A Bridge Between Biochemistry, Physiology and Sport Science. *Sports Med,* 2003; 33 (6): 407–426. https://doi.org/10.2165/00007256-200333060-00003
13. Jones AM, Burnley M, Black MI, Poole DC, Vanhatalo A. The maximal metabolic steady state: redefining the 'gold standard'. *Physiol Rep.* 2019;7 (10), e14098. https://doi.org/10.14814/phy2.14098
14. Skinner JS, McLellan TM. The transition from aerobic to anaerobic metabolism. *Res Q Exerc Sport*. 1980; 51(1):234–48. https://doi.org/10.1080/02701367.1980.10609285
15. Onorati P, Martolini D, Valli G, Laveneziana P, Marinelli P, Angelici E et al. A Simplified Approach for the Estimation of the Ventilatory Compensation Point. *Med. Sci. Sports Exerc*. 2012;44(4): 716–724. https://doi.org/10.1249/MSS.0b013e318237fb5f
16. Conconi F, Michele F, Ziglio PG, Droghetti P, Codeca L. Determination of the anaerobic threshold by a noninvasive field test in runners. *J. Appl. Physiol.;Respirat. Environ. Exercise Physiol*. 1982; 52(4):869–873. https://doi.org/10.1152/jappl.1982.52.4.869
17. Mankowski RT, Michael S, Rozenberg R, Stokla S, Stam HJ, Praet SF. Heart-rate variability threshold as an alternative for spiro-ergometry testing: a validation study. *J Strength Cond Res*. 2017; 31(2): 474–479. https://doi.org/10.1519/JSC.0000000000001502
18. Nascimento EM, Pedutti MA, Kiss DM, Santos

TM, Lambert M, Pires FO, Determination of Lactate Thresholds in Maximal Running Test by Heart Rate Variability Data Set. *Asian J Sports Med*. 2017; 8(3):e58480. https://doi.org/10.5812/asjsm.58480
19. Latasa I, Cordova A, Quintana-Ortí G, Lavilla-Oiz A, Navallas J, Rodriguez-Falces J. Evaluation of the Electromyography Test for the Analysis of the Aerobic-Anaerobic Transition in Elite Cyclists during Incremental Exercise. *Appl. Sci.* 2019; 9: 589. https://doi.org/10.3390/app9030589
20. Wasserman K. Breathing during exercise. *N Engl J Med*. 1978; 298(14):780–5. https://doi.org/10.1056/NEJM197804062981408
21. Whipp BJ. Ventilatory control during exercise in humans. *AnnuRev Physiol*. 1983; 45:393–413. https://doi.org/10.1146/annurev.ph.45.030183.002141
22. Stefanov LG, Nejkov SE. Determination of Anaerobic Threshold by a new approach through the incremental exercise using proportion in heart rate and pulmonary ventilation changes in rowers. *Pedagogy of Physical Culture and Sports*, 2021;25(2):89–97: https://doi.org/10.15561/26649837.2021.0203
23. Beaver WL, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. *J Appl. Physiol*. 1986; 60 (6): 2020–2027. https://doi.org/10.1152/jappl.1986.60.6.2020
24. Pühringer M, Ring-Dimitriou S, Stöggl T, Iglseder B, Paulweber B. Comparison of visual, automatic and semiautomatic methods to determine ventilatory indices in 50 to 60 years old adults. *Journal of Sports Sciences*, 2020; 38:6, 692–702. https://doi.org/10.1080/02640414.2020.1725993
25. Ekkekakis P, Lind E, Hall EE, Petruzzello SJ. Do regression-based computer algorithms for determining the ventilatory threshold agree? *Journal of Sports Sciences*, 2008; 26(9): 967 – 976. https://doi.org/10.1080/02640410801910269
26. Korkmaz ES, Polat M, Soyal M, Aydoğan S. The Relationship between the Isocapnic Buffering Phase and Ventilatory Threshold in Endurance Athletes and Team Sport Athletes during an Incremental Exercise Test. *Ann Appl Sport Sci*. 2018; 6 (1) :1–9. https://doi.org/10.29252/aassjournal.6.1.1
27. Giavarina D. Understanding Bland Altman analysis. *Biochemia Medica*. 2015; 25(2):141–51. https://doi.org/10.11613/BM.2015.015
28. Altman DG, Bland JM. Measurement in Medicine: the Analysis of Method. *The Statistician*. 1983; 32:307–317. https://doi.org/10.2307/2987937
29. Kenney WL, Wilmore JH. Costill DL. *Physiology of sport and exercise*. 5th Human Kinetics; 2012.
30. Plowman SA, Smith DL. *Exercise physiology for health, fitness, and performance*. 3rd ed. Lippincott Williams & Wilkins; 2011.
31. Bosquet L, Léger L, Legros P. Methods to Determine Aerobic Endurance. *Sports Med.* 2002; 32(11):675–700. https://doi.org/10.2165/00007256-200232110-00002
32. Santos EL, Giannella-Neto A. Comparison of computerized methods for detecting the ventilatory thresholds. *Eur J Appl Physiol*. 2004; 93: 315–324. https://doi.org/10.1007/s00421-004-1166-6
33. Wyatt FB. Comparison of Lactate and Ventilatory Threshold to Maximal Oxygen Consumption: A Meta-Analysis. *Journal of Strength and Conditioning Research*, 1999; 13(1): 67–71. https://doi.org/10.1519/00124278-199902000-00012

Information about the author:

Lachezar G. Stefanov; http://orcid.org/0000-0001-5380-3446; luchos@nsa.bg; Sofia National Sports Academy, Bulgaria

Cite this article as:
Stefanov LG. Comparison between determination of second anaerobic threshold by respiratory compensating point and X-method in rowers. *Pedagogy of Physical Culture and Sports*, 2022;26(2):101–110.
https://doi.org/10.15561/26649837.2022.0204

Received: 11.02.2022
Accepted: 23.03.2022; Published: 30.04.2022

ORIGINAL ARTICLE

Knowledge, attitudes and practices of injury prevention towards lateral ankle sprain among amateur football players in Brunei

Mohammad Aiman Hakeem Haji Mohammad Som[1ABCD], Rajkumar Krishnan Vasanthi[1ABCD], Ambusam Subramaniam[2ACD], Ali Md. Nadzalan[3ACD]

[1]*Faculty of Health and Life Sciences, INTI International University, Nilai, Malaysia*
[2]*Faculty of Medical and Health Sciences, University Tunku Abdul Rahman, Selangor, Malaysia*
[3]*Faculty of Sports Science and Coaching, Sultan Idris Education University, Tanjong Malim, Malaysia*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; ; E – Funds Collection

Abstract

Background and Study Aim — Football is a globally recognized sport and played both professionally and recreationally. As it is a physically challenging sport, it must inform players on preventing injuries from occurring or reoccurring. This study aimed to assess the knowledge, attitudes and practices on injury prevention towards lateral ankle sprain (LAS) among amateur football players in Brunei.

Material and Methods — A total of 140 respondents participated in the cross-sectional study who fit into the inclusion criteria. An online questionnaire was adapted and shared with amateur football players in Brunei from September 2021 to October 2021. Questions were related to (1) demographic data; (2) injury history; (3) knowledge; (4) attitudes; and (5) practices to prevent a lateral ankle sprain.

Results — Tendon/ligament injury was the highest amount of frequency at n= 97 (69.3%), in which the participants have sustained it throughout their playing years. More people perceive that the cause of injury was mainly due to lack of physical fitness 84.2%, fatigue/exhaustion 55%, uncured injuries 49.3% and contact with other players 75.7%. 84.3% agreed that the importance of injury prevention is crucial. Participants reported that the injury prevention methods are mainly used to prevent lateral ankle sprain were stretching 81.4%, specific warm-up training 79.3% and taping 67.9%.

Conclusions — Our results show that players think that injury prevention is critical, yet most of them are still under-informed about avoiding injuries properly. Despite evidence that stretching is ineffective in preventing injuries, many athletes stretch to prevent damage. Warm-up training and taping are two other standard injury prevention techniques these amateur football players use. Future research should raise exercise knowledge among Brunei's amateur football players to prevent injuries.

Keywords: amateur football players, athletic injuries, preventions, attitude

Introduction

Football is widely known worldwide and is acknowledged as the world's most famous single sport [1]. In Brunei, football is a trendy sport among all ages. The National Football Association Brunei Darussalam, the governing body for football in Brunei, helps to promote and regulate the sport and all aspects of it. However well prepared a player can be, football itself has demanding physical capabilities to play. The typical distance covered by a top-level outfield player is about 10-13 km [2], surrounded by low- and high-intensity running. Other energy-intensive activities include short accelerations, tackles and jumps, which are commonly associated with a prevalence of ankle sprains [3]. The study reported that half of the injuries were associated with contact situations such as tackling, collision, kicked or another contact.

The number of amateur players in this world is higher than that of professional football players. Participation in recreational sport has been steadily increasing as the years go by [4]. According to current literature, amateur players have lower injuries than professional athletes during matches, as reported [5]. Injuries among Spanish male amateur football players studied the differences between the risk of injury and characteristics between Dutch amateur and professional football players [6]. In the scientific literature on the knowledge of injury prevention for LAS, there are limited studies investigating amateur football players' knowledge to prevent the injury. A large number of studies were targeted towards professional football players than amateur players [7]. However, in theory, amateur players tend to get more injured due to the lower fitness and technique levels than professional players. With research on experienced players, awareness of injury prevention strategies is still insufficient [8]. A cross-sectional study on the knowledge of football players in Tabuk, Saudi Arabia [9] showed that the players reported the significant risk factors to obtain the injuries were due to lack of stretching, lack of warm-up and the absence of bracing. The researchers concluded that the players have little knowledge of physical therapy measures towards injury prevention.

doi:10.15561/26649837.2022.0205

In a study [10], 90% believed it is vital to prevent injuries, and 85% are optimistic about prevention programmes, even though the program addresses only intrinsic risk factors. A key finding noted from the study [10] reviewed from the antecedent segment was that 76.5% of the elite female football players previously received advice on the injury prevention programmes, and 80% reported that their teams conducted the injury prevention training twice a week as recommended to reduce injuries. Even with the high percentage of players practising injury prevention, it is still a surprise that some elite football players did not have their physiotherapists, physicians, sports scientists and conditioning coaches. Despite the fact they did not have dedicated medical support, the elite female players are still well informed on injury prevention. They have high motivation to implement and practice injury prevention programmes.

High injury recurrence rate concerning ankle sprains as up to 70% of patients reported residual symptoms and injury recurrence [11]. A reason for us to dive into injury prevention methods among amateur football players as they do not have the quality of resources for rehabilitation and recovery as the professional players when they are injured, as prevention has always been better than the cure.

This research aims to measure the knowledge, attitudes, and practices (KAP) to prevent lateral ankle sprain injury among amateur football players in Brunei. Football players require knowledge on injury prevention, as LAS are among the common types of ankle injury [12] they can get while training or competing.

Materials and Methods

Participants

In this cross-sectional survey, an online questionnaire through Google forms was circulated among amateur football players in Brunei. Among 151 responses, 11 were excluded as 5 were professional football players and 6 had underlying chronic medical, cardiovascular and respiratory conditions. We included one hundred forty total responses in the study with a mean age of 23.87±3.29. Faculty Research and Ethics Committee approved the study with reference no: INTI-IU/FHLS-RC/BPHTI/1NY12021/015. Participants who agreed to participate in the study filled in an informed consent form and all data received were kept confidential.

Both genders between 18-40 years old and must reside in Brunei who plays football for recreation and does not be paid to participate in competitions and training were included in the study. Participants were excluded if they were uncooperative and with chronic medical, cardiovascular and respiratory conditions.

Procedure

The survey was shared using the primary investigator's various social media platforms, targeting the amateur football players in Brunei. The data collection period was from 1st September 2021 until 30th September 2021. However, data collection was extended for another one month until 31st October 2021 to increase the number of responses.

The survey was developed by [13] from their study on "Perceptions of football players regarding injury risk factors and prevention strategies". The primary investigator has obtained permission from the authors before using the survey. The questionnaire covers five main segments: demographic data, history of injury, knowledge on the injury and its risk factors, beliefs, and practices regarding preventive measures. However, the primary investigator did not use the whole questionnaire and only adapted the questions related to the investigator's research objectives and relevance. In this case, sections other than ankle and foot injuries were omitted.

In the first segment, we collected demographic data such as gender, age, height and weight, followed by questions on participation in football as the second segment. Under the participation in football section, players are asked how long they have been playing, how many hours a week they play on average, and if they participate in any sport besides football. The third segment included questions about their injuries in football involving their ankle or foot, such as the year of injury, the type of injury suffered (contusion, bruise, bone fracture, muscle injury, joint/capsule injury, and tendon/ligament injury), and the year of injury.

Also included the side of injury, time loss from playing, time of occurrence of injury (whether it was in-game, warm-up or others).

A fourth segment talked about people's beliefs about their injuries and how they try to prevent them. This segment spoke about their beliefs about the leading causes of their injuries and how vital and effective injury prevention methods and practices are.

We collected the Google form responses at the end of the data collection period.

Statistical analysis

The Statistical Package of Social Sciences (SPSS) version used 28.0.0 to analyze the statistical data collected.

Demographic data such as gender, age, height and weight were evaluated using descriptive analysis. Categorical variables such as years of playing football, plying time in a week, history and type of ankle and foot injury suffered and time loss from playing football due to injuries will be shown in the form of frequencies (n), percentages (%) for discrete data and mean and standard deviation (SD) for continuous data, wherever applicable.

Results

Total 140 responses included in the study. There are 136 males and 4 females who participated in this study. The mean age of the participants, height, body mass and years of playing were shown in the Table 1 below.

In the section regarding the participants' participation in playing football, we found that the mean number of years they have been playing football is 12.99 years. More than half (51.4%) of the participants play football approximately 1 hour per week.

In Table 3, among the 140 respondents, the type of injury, history of ankle or foot injuries, side of injuries and days not playing football due to injury were shown in the table 2.

More people perceive that the cause of injury was mainly due to lack of physical fitness, fatigue/exhaustion, uncured injuries, contact with other players and material problems (such as shoes and flooring). In overall the knowledge, beliefs, attitude, and injury preventions practice were shown in the Table 4.

Table 1. Participants' demographic data

Demographic Characters	Mean	Std. Deviation
Age (in years)	23.87	3.29
Height (in meters)	1.73	0.05
Weight (in kilograms)	74.47	10.37
Years playing football (in years)	12.99	4.05

Table 2. Respondents' playing hours in a week

Playing hrs per week	Frequency (n)	Percentage (%)
Approx . 1h/week	72	51.40%
Approx . 2h/week	47	33.60%
Approx . 3h/week	5	3.60%
Approx . 4h/week	7	5%
Approx . 5h/week	2	1.40%
Approx . More than 6h/week	6	4.30%

*h= hours, Approx. =Approximately

Table 3. Type, history and side of ankle injury encountered by the players and days not playing football due to injury

Participants' Injury Rates	Frequency (n)	Percentage (%)
Types of injury sustained		
Tendon/ligament injury	97	69.3
Contusion/bruise	45	32.1
Muscle injury	27	19.3
Joint/capsule injury	17	12.1
Bone fracture	11	7.9
Reported history of ankle or foot injuries		
One or more ankle or foot injury	122	87.1
Never had an ankle or foot injury	18	12.9
Side of ankle injuries		
Right	60	49.2
Left	41	33.6
Both	21	17.2
Days not playing football due to injury		
More than 28 days	73	59.8
7 – 27 days	40	32.8
1 – 6 days	9	7.4

Table 4. Participants' knowledge, beliefs and attitudes on LAS and their injury prevention practices.

Participants' Perceptions	Frequency (n)	Percentage (%)
Importance on injury prevention		
Very important	118	84.2
Important	22	15.7
Opinion on whether participants are well informed or not on injury prevention (n = 140)		
Yes – adequately informed	56	40
No – not adequately informed	84	60
Participants' beliefs on the causes of their LAS		
Lack of physical fitness	118	84.2
Contact with other players	106	75.7
Fatigue/exhaustion	77	55.0
Material problems (shoes/flooring)	74	52.9
Uncured injuries	69	49.3
Muscular deficits (power deficits or muscular imbalances)	33	23.6
Concentration or attention deficits	22	15.7
Coordination deficits	15	10.7
Climatic conditions	7	5.0
Incorrect nutrition	6	4.3
Others	2	1.4
Injury prevention practices		
Stretching	114	81.4
Specific warm-up training	111	79.3
Taping (kinesio taping or stabilizing taping)	95	67.9
Special joint-related training	55	39.3
Wearing bandages or orthoses	51	36.4
Shin guards	18	12.9
Shoe inserts	12	8.6
Face mask	2	1.4

Discussion

This study investigated the KAP of injury prevention towards lateral ankle sprain among amateur football players in Brunei. The study adopted a self-reporting questionnaire developed by [13] that the author has permission. The self-reported questionnaire showed that the mean age of the players was 23.87±3.29 as the inclusion criteria were between the 18 – 40 age group with mean years of playing football at about 13 years. As a result, most players who participated in the study began playing football at the age of ten. With over ten years of amateur playing experience, there is little doubt that injuries are a part of the game.

Additionally, our study discovered that roughly 51.4 percent of amateur football players in Brunei participated in approximately one hour of football each week over the last year. This is understandable, given Brunei, like the rest of the world, was impacted by the global pandemic COVID-19. The pandemic led to restricted operation hours for these playing grounds. It reduced the number of players on the field, turf, or football ground. According to the health ministry's guidelines, these complexes limited the capacity to only 30% as part of their de-escalation phase. The fields then reopened slowly by levels every four weeks, which led to 100% reopening of the areas by August 2020 [14].

The type of injuries that the participants suffered reflects current literature [7], in which 122 of the total 140 respondents had one or more ankle or foot injuries. The tendon/ligament injury has the highest incidence in injury, followed by contusion or bruise. Half of the injuries occur during the game, and the remaining half comes from either during training or others. Participants' knowledge of the cause of injury was also recorded, in which 84.2% believe the grounds of their injuries were from lack of physical fitness. As football is a physically demanding sport (Fong et al., 2003), general fitness is needed to excel. A study [15] reported that age, morphology and physical fitness are influential parameters of football performance at elite football. Although these data are valuable, evidence catering amateur level is lacking. Still, the importance of better fitness should be emphasized regardless of the playing group, with superior physical performance being a predictor of success in football games [16].

Subsequently, fatigue, exhaustion, and uncured injuries lead to several internal risk factors. The high frequency with which participants reported contact with other players and material difficulties such as shoes and flooring is shocking, given that external risk factors have been identified as causes of injuries in recent years, causing alarm in the football community [10], [13]. About 75% of the participants perceive that contact with other players is a cause of their injuries. Roughly 40-50% of the amateur football players in our study reported that their injury was due to contact. Half of the participants who had this contact injury were injured in a game. The findings supported that ankle sprain was due to contact with other players are in line with those previously mentioned in literature [17], [18]. Contact injuries, otherwise known as traumatic injuries, are still high in football regardless of their playing level, according to other previous studies reported [19]–[21].

52.9% of our respondents believe that the cause of injury that amateur footballers identified is the material problems regarding shoes and flooring, supported by a systematic review conducted on the prevention of sports injuries. We have to accept that shoes cannot support the ankle structure compared to rigid orthoses or stabilizers. Additionally, they could contribute to the twisting force when an ankle sprain occurs. Using proper mechanically designed shoes for football should be considered when playing, even among amateur players, as this is a matter of safety and practice to prevent injuries [22].

Following our findings, stretching 81.4%, specific warm-up training 79.3% and taping 67.9% (Kinesio-taping or stabilizing taping) dominate the injury prevention practices that amateur football players in Brunei actively use to prevent LAS. Stretching has been an interest in sports research for the past 20 years, in which there are conflicting shreds of evidence in their effects on different individuals. A systematic review [22] revealed insufficient evidence to endorse or discontinue routine stretching before or after exercise to prevent injury among competitive or recreational athletes. Further research is needed to identify the essential role of stretching in sports. In their systematic review, a study [23] also mentioned no evidence of the benefits of passive or active stretching for injury prevention in sports. This suggests that evidence-based knowledge on stretching are still lacking among these players.

Specific warm-up training is also one of the injury prevention practices that participants perform either before or during the game at 79.3%. A systematic review [24] on the impact of this program reduced between 30-70% in the number of injured players. We concluded that the program can be a fundamental tool to minimize the risk of injuries and should be made available and give recognition, especially to the amateur players, as their injuries may impact their health and social participation.

Another type of injury prevention practice that the amateur players in Brunei reported is either Kinesio taping or stabilizing taping as an external measure of injury prevention. Taping gives mechanical joint support and enhances proprioception, especially when using the ankle in sporting activities. There has been conflicting evidence on taping in literature. Nonetheless, it has been said that the consensus is that taping does help prevent the re-injury of the athletes, and it may have a placebo effect [25]. As it may give athletes confidence in activities, research has reported that taping does not negatively impact performance. There is still a need for research regarding the effects of taping in injury prevention, as current research gives insufficient evidence on their benefits.

In this study, the researcher has made a few limitations. Recall bias might be present as the participants remember their history of injuries. There is also no accurate outcome measure to identify the level of KAP of the amateur football players, as the survey was only able to take in their opinions and cannot test their knowledge correctly. It is relatively low on matters of response rate as only 140 participants were included from the 151 who participated. The minimum sample size we determined before the research is 334, which may be affected by the pandemic. Future research may examine the relationship between playing years and the frequency of lateral ankle sprains or general lower limb injuries among Brunei's amateur football players. Injury prevention programme, in the hopes of reducing the number of football injuries, particularly among amateurs. As evidence-based practices are still deficient among the participants, sports scientists and coaches, these parties should start implementing proper awareness, education, and keeping up with the ever-changing sciences to protect further the people who love the sport.

Conclusion

Our research identified that majority of the amateur football players had sustained injuries throughout their playing years, with tendon/ligament injury being the highest incidence. Players generally believe that lack of physical fitness, fatigue or exhaustion and uncured injuries are the leading intrinsic causes of their injuries. In contrast, contact with other players and material problems such as shoes and flooring are the extrinsic causes. All players agree that injury prevention is essential though most of them are still inadequately uninformed on the proper methods to prevent injuries. Many players practise stretching to avoid injuries, despite evidence that it is not beneficial in preventing injuries. Specific warm-up training and taping are other highly performed injury prevention practices by these amateur football players. Future studies should identify the awareness of exercise programs among amateur football players in Brunei.

References:

1. Gardasevic J, Bjelica D, Vasiljevic I. The strength of kicking the ball after preparation period with U15 football players. *Sport Mont.* 2017;15(2):39–42.
2. Bangsbo J. Physiological Demands of Football. *Sport Sci,* 2014;27(125):1–6.
3. Cloke DJ, Spencer S, Hodson A, Deehan D. The epidemiology of ankle injuries occurring in English Football Association academies. *Br J Sports Med*. 2009;43(14):1119–25. https://doi.org/10.1136/bjsm.2008.052050
4. Dvorak J, Graf-Baumann T, Peterson L, Junge A. Football, or soccer, as it is called in North America, is the most popular sport worldwide. *The American Journal of Sports Medicine,* 2000;28: S1-2.
5. Herrero H, Salinero JJ, Del Coso J. Injuries among spanish male amateur soccer players: A retrospective population study. *Am J Sports Med*. 2014;42(1):78–85. https://doi.org/10.1177/0363546513507767
6. Anne-Marie van Beijsterveldt AMC, Stubbe JH, Schmikli SL, Van De Port IGL, Backx FJG. Differences in injury risk and characteristics between Dutch amateur and professional soccer players. *J Sci Med Sport*. 2015;18(2):145–9. http://dx.doi.org/10.1016/j.jsams.2014.02.004
7. Kofotolis ND, Kellis E, Vlachopoulos SP. Ankle sprain injuries and risk factors in amateur soccer players during a 2-year period. *Am J Sports Med*. 2007;35(3):458–66. https://doi.org/10.1177/0363546506294857
8. Hawkins RD. A preliminary assessment of professional footballers' awareness of injury prevention strategies. *Br J Sports Med*. 1998;32(2):140–3. https://doi.org/10.1136/bjsm.32.2.140
9. Al Amer HS, Mohamed SHP. Prevalence and Risk Factors of Ankle Sprain Among Male Soccer Players in Tabuk, Saudi Arabia: A Cross-Sectional Study. *Open Sports Sci J.* 2020;13(1):27–33. https://doi.org/10.2174/1875399x02013010027
10. Geertsema C, Geertsema L, Farooq A, Harøy J, Oester C, Weber A, et al. Injury prevention knowledge, beliefs and strategies in elite female footballers at the FIFA Women's World Cup France 2019. *Br J Sports Med.* 2021;55(14):801–6. https://doi.org/10.1136/bjsports-2020-103131
11. Anandacoomarasamy A, Barnsley L. Long term outcomes of inversion ankle injuries. *Br J Sports Med.* 2005;39(3):1–5. https://doi.org/10.1136/bjsm.2004.011676
12. Fong DTP, Hong Y, Chan LK, Yung PSH, Chan KM. A systematic review on ankle injury and ankle sprain in sports. *Sport Med*. 2007;37(1):73–94. https://doi.org/10.2165/00007256-200737010-00006
13. Zech A, Wellmann K. Perceptions of football players regarding injury risk factors and prevention strategies. *PLoS One*. 2017;12(5):1–11. https://doi.org/10.1371/journal.pone.0176829
14. *Media Statement from Ministry of Health Brunei Darussalam* [Internet]. 2020. Available from: https://www.moh.gov.bn/SitePages/pressreleaseCOVID-19.aspx
15. Matković BR, Misigoj-Duraković M, Matković B, Janković S, Ruzić L, Leko G, et al. Morphological differences of elite Croatian soccer players according to the team position. *Coll Antropol*. 2003;27 Suppl 1:167–74.
16. le Gall F, Carling C, Williams M, Reilly T. Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *J Sci Med Sport*. 2010;13(1):90–5. https://doi.org/10.1016/j.jsams.2008.07.004
17. Peterson L, Junge A, Chomiak J, Graf-Baumann T, Dvorak J. Incidence of football injuries and complaints in different age groups and skill-level groups. *Am J Sports Med*. 2000;28(5 SUPPL.). https://doi.org/10.1177/28.suppl_5.s-51
18. Onate JA, Everhart JS, Clifton DR, Best TM, Borchers JR, Chaudhari AMW. Physical Exam Risk Factors for Lower Extremity Injury in High School Athletes: A Systematic Review. *Clin J Sport Med.* 2016;26(6):435–44. https://doi.org/10.1097/JSM.0000000000000284
19. Inklaar H, Jakobsen BW, Nielsen AB, Yde J, Krøner K, Møller-Madsen B, et al. Epidemiology and traumatology of injuries in track athletes. *Inj Prev,* 2014;48(1):1235–9.
20. Ekstrand J. The Incidence of Ankle Sprains in Orienteering. *Sci J Orienteer*. 1990;6(1):3–9. https://doi.org/10.1177/107110079001100108
21. Inklaar H. Soccer Injuries: I: Incidence and Severity. *Sport Med Eval Res Exerc Sci Sport Med.* 1994;18(1):55–73. https://doi.org/10.2165/00007256-199418010-00006
22. Thacker SB. Public health surveillance and the prevention of injuries in sports: What gets measured gets done. *J Athl Train*. 2007;42(2):171–2.
23. Aaltonen S, Karjalainen H, Heinonen A, Parkkari J, Kujala UM. Prevention of sports injuries: systematic review of randomized controlled trials. *Arch Intern Med*. 2007;167(15):1585–92. https://doi.org/10.1001/archinte.167.15.1585
24. Barengo NC, Meneses-Echávez JF, Ramírez-Vélez R, Cohen DD, Tovar G, Enrique Correa Bautista J. The impact of the fifa 11+ training program on injury prevention in football players: A systematic review. *Int J Environ Res Public Health*. 2014;11(11):11986–2000.

https://doi.org/10.3390/ijerph111111986
25. Sawkins K, Refshauge K, Kilbreath S, Raymond J. The placebo effect of ankle taping in ankle instability. *Med Sci Sports Exerc*. 2007;39(5):781–7. https://doi.org/10.1249/MSS.0b013e3180337371

Information about the authors:

Mohammad Aiman Hakeem Haji Md Som; https://orcid.org/0000-0002-3660-5437; aiman.104@live.com; INTI International University; Nilai, Malaysia.

Rajkumar Krishnan Vasanthi; (Corresponding author); https://orcid.org/0000-0001-6866-8224; rajkumarhari@yahoo.co.in; INTI International University; Nilai, Malaysia.

Ambusam Subramaniam; https://orcid.org/0000-0002-5745-4084; ambusam_7@hotmail.com; University Tunku Abdul Rahman; Selangor, Malaysia.

Ali Md. Nadzalan; https://orcid.org/0000-0002-0621-2245; ali.nadzalan@fsskj.upsi.edu.my; Sultan Idris Education University; Tanjong Malim, Malaysia.

Cite this article as:
Haji Md Som MAH, Vasanthi RK, Subramaniam A, Nadzalan AM. Knowledge, attitudes and practices of injury prevention towards lateral ankle sprain among amateur football players in Brunei. *Pedagogy of Physical Culture and Sports*, 2022;26(2):111–117.
https://doi.org/10.15561/26649837.2022.0205

Received: 20.02.2022
Accepted: 27.03.2022; Published: 30.04.2022

ORIGINAL ARTICLE

Modeling of functional preparedness of women 25-35 years of different somatotypes

Yuriy M. Furman[1AVSD], Vyacheslav M. Miroshnichenko[1ABVSD], Victoria Yu. Boguslavska[1AVDE], Natalia V. Gavrilova[1AVDE], Oleksandra Yu. Brezdeniuk[1AVDE], Svitlana V. Salnykova [2ABDE], Viktoria V. Holovkina[1AVDE], Igor Vypasniak[3CDE], Vasyl Lutskyi[3CDE]

[1]*Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Ukraine*
[2]*Vinnytsia Institute of Trade and Economics of Kyiv National University of Trade and Economics, Ukraine*
[3]*Vasyl Stefanyk Precarpathian National University, Ukraine*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; ; E – Funds Collection

Abstract

Background and Study Aim The level of functional preparedness of the population is influenced by many factors. The greatest influence is exerted by the economic condition of the country, climatic features of the region, food quality, environmental factor, social status of the population. Therefore, functional readiness standards should be updated periodically. For an objective assessment of functional readiness, all energy potential should be considered: aerobic, anaerobic lactatic and alactatic. Women of different somatotypes have significant differences in the degree of development of indicators of functional preparedness. The models of functional preparedness developed by us for women of different somatotypes will clearly demonstrate significant differences in the level of preparedness in representatives of different somatotypes. The aim of the study is to develop standards of functional readiness for women aged 25-35 and models of functional preparedness for women of different somatotypes.

Material and Methods The study involved women aged 25-35 years (n = 392). Somatotype was determined in all subjects. The power of aerobic energy supply processes was determined by the method of bicycle ergometry according to the PWC 170 test. The threshold of anaerobic metabolism was determined by the test with a stepwise increasing load. The capacity of anaerobic lactatic energy supply processes of muscular activity was determined by a bicycle ergometric 60-second test. The power of anaerobic lactatic and alactatic energy supply processes was determined by Wingate anaerobic tests WAnT 30 and WAnT 10. Standards of functional preparedness were developed according to the author's method based on the rule 3σ.

Results Functional preparedness standards have been developed for women aged 25-35 according to the full range of muscular energy supply regimes. Models of functional preparedness for women 25-35 years of different somatotypes have been developed.

Conclusions The developed standards are based on modern experimental data and consider all human energy potential (aerobic, anaerobic lactatic and anaerobic alactatic). Standards of functional preparedness cannot be universal for different countries and even different regions of large countries. Models of functional preparedness of women of different somatotypes show a significant difference from the standards set for women without somatotype. Somatotype should be considered when assessing indicators of functional preparedness.

Keywords: standards, aerobic, anaerobic productivity, mature age.

Introduction

The level of functional preparedness of the population is influenced by many factors. The greatest influence has the economic condition of the country, climatic features of the region, food quality, environmental factors, social status of the population [1]. As these factors are not stable, the functional capabilities of the population are also changing. Therefore, functional preparedness standards should be updated periodically. Thus, a study by Davidson and McNaughton [2] found that women aged 22.6 ± 7.6 years who had no experience of systemic physical activity VO_{2max} averaged 34.1 ± 2.1 ml·min^{-1}·kg^{-1}. The study by Astorino et al. [3] found that the average value of VO_{2max} in women aged 22.8 ± 2.8 years is 41,1 ml·min^{-1}·kg^{-1}.

Currently, there are standards of aerobic performance on the basis of VO2max rel. for all age groups of the adult population of the United States [4]. $VO_{2max\ rel.}$ standards for all age groups have been developed for the population of the USSR [5, Art. 35]. A "safe level of health" for women and men has been defined for the population of Ukraine, which is assessed by the $VO_{2max\ rel.}$ indicator [6]. Also identified

doi:10.15561/26649837.2022.0206

standards of aerobic performance on the threshold of anaerobic metabolism (TAM) for men [7]. As all of the above standards were developed more than 20 years ago, they need to be updated.

Experts in the physiology of motor activity note that information on functional readiness only in terms of aerobic performance is incomplete [8]. There are standards of anaerobic performance focused on professional activities. Such developments are available for athletes in various sports [9] and criteria for specific professions (firefighters [10], special forces [11], police [12]). No standards for anaerobic productivity for the population have been identified.

We have developed standards for assessing aerobic and anaerobic productivity for girls and men aged 17-19 [13]. Furman et al. [14] developed standards of functional preparedness for women and men aged 20-22 years and for adolescents aged 11-12 years [15]. There is a need to develop standards of aerobic and anaerobic performance for other age groups.

In modern theory and practice of sport, the method of modeling has become widely used [16]. The use of modeling in health-improving physical culture is a reserve for improving the efficiency of classes. Women 25-35 years of age of different somatotypes have significant differences in aerobic and anaerobic performance [17]. Significant differences in V_{o2max} in representatives of different somatotypes indicate Goran Spori et al. [18]; threshold of anaerobic metabolism Zimnitskaya et al. [19]; indicators of anaerobic lactate productivity Ryan-Stewart et al. [20]. Therefore, we hypothesized that the models of functional preparedness developed by us for women of different somatotypes will clearly demonstrate significant differences in the level of preparedness in women of different somatotypes. Such data can be convincing evidence of the need to consider somatotype in the assessment of functional preparedness.

The aim of the study. Develop standards of functional preparedness for women aged 25-35 and models of functional preparedness for women of different somatotypes.

Material and Methods

Participants

The study involved females 25-35 years old (the first period of mature age) n=392. All subjects in the past had no experience in sports. Each subject gave written consent to participate in the experiment.

Procedure

The power of aerobic energy supply processes of muscular activity was investigated by the indicator of maximum oxygen consumption ($VO_{2\,max}$). $VO_{2\,max}$ was determined by the Karpman et al. [21] method. For this purpose was used a bicycle ergometric test of the PWC 170 version. The subjects performed two loads of different power. The power of the first load (N_1) was 1 W per 1 kg of body weight, the other (N_2) - 2 W per 1 kg of body weight. Pedaling frequency - 60 revolutions per 1 minute. The duration of each load was 5 minutes with 3 minutes interval. At the end of each load, the heart rate (f_1 and f_2) was determined. PWC 170 was calculated according to the algorithm [22]. To determine the values of Vo2 max, the value of PWC 170 abs was substituted into equation 1:

$$VO_{2max\ abs.} = 1.7 \cdot PWC\ 170_{abs.} + 1240, \qquad (1)$$

where , $VO_{2\ max\ abs.}$ displayed in $ml{\cdot}min^{-1}$;
$PWC170_{abs.}$ displayed in $kg{\cdot}min^{-1}$.

The threshold of anaerobic metabolism (TAM) was determined by the test of Conconi et al. [23] in a modification of Furman [5, Art. 37-38]. The subjects performed a stepwise increasing load on the ergometer starting from a power of 60 watts, adding 10 watts at each stage. The duration of work and the frequency of pedaling at each stage are constant - the duration is 40s, and the frequency is 60 rpm^{-1}. At the end of each stage, heart rate was recorded. The level of TAM corresponded to the inflection point on the graph of heart rate growth. Results were presented in W.

To determine the capacity of anaerobic lactatic energy supply processes of muscular activity was used a method developed by Shogy et al. [24]. This method involves determining the maximum quantity of mechanical work for 1 minute (MQMK). The subject performed a bicycle ergometric load with 1 min duration, power of 225 W and maximum pedaling frequency. Results were presented in $kg{\cdot}min^{-1}$.

The power of anaerobic alactatic energy supply processes of muscular activity was determined using the Wingate anaerobic test WAnT10 [25]. This test consists in performing a bicycle ergometric load 10sec duration with a power of 225 W and maximum possible pedaling frequency. The number of full pedal revolutions was counted. By mathematical calculations, the result was expressed in $kg{\cdot}min^{-1}$.

The power of anaerobic lactatic energy supply processes of muscular activity was determined using the Wingate anaerobic test (WAnT30) [25]. The conditions of this test are similar to the WAnT10 test. The difference is duration of the load that lasted 30 seconds. Result was expressed in $kg{\cdot}min^{-1}$.

To increase the informativeness of all indicators, absolute and relative values were studied. All tests were performed on a Christopeit Sport AX-1 bicycle ergometer (Christopeit, Germany).

Somatotype was determined by the Carter et al. [26] method.

Statistical analysis

Initially, the STATISTICA 13 program checked the data series for compliance with the normal distribution law. Determined: - arithmetic mean, σ - standard deviation.

Standards of functional preparedness were developed according to the author's method. This technique is based on the rule 3σ. The main condition was that the data series correspond to the normal distribution law. The range of values of ± 0.5σ of the data series of all studied women aged 25-35 years (n = 392) was taken as the average level of the trait. The scheme according to which the rating scale is built is shown in Table 1. Such calculations should be made based on a large number of experimental data of persons of the same age, sex, region of residence, lack of experience in sports. This technique is copyrighted.

Results

We have developed standards of functional fitness for women aged 25-35 for the full range of muscle energy of muscular activity (Table 2).

Having determined the somatotype, it was found that 4 somatotypes are characteristic for women aged 25-35: endomorphic, ectomorphic, endomorphic-mesomorphic and balanced. Using the author's standards, we developed models of functional preparedness for women of different somatotypes, which are shown in tables 3, 4, 5, 6.

In women of endomorphic somatotype, the indicators of aerobic productivity of the body (VO_{2max}, TAM) are at a lower level than the indicators of anaerobic productivity of the body (MQMK, WAnT 30, WAnT 10) (table 3).

Opposite tendencies were found in women of ectomorphic somatotype. Indicators of aerobic productivity of an organism (VO_{2max}, TAM) correspond to "above average" and "high" levels. Indicators of anaerobic productivity (WAnT 30, WAnT10) correspond to the level "below average" (table 4).

For women of endomorphic-mesomorphic somatotype, the "average" level of aerobic productivity (VO_{2max}, TAM) and capacity of anaerobic lactate productivity (MQMK) is characteristic. "High" and "above average" levels are characteristic of the performance of anaerobic lactatic and alactatic

Table 1. Scheme of formation of an assessment scale for indicators of functional preparedness

Interval	% of all values of the general population	Evaluation scale
> 2.0 σ	≈ 2	very high
1.1 – 2.0 σ	≈ 13	high
0.6 – 1.0 σ	≈ 17	above average
± 0.5 σ	≈ 34	average
-0.6 – -1.0 σ	≈ 17	below average
-1.1 – -2.0 σ	≈ 13	low
< -2.0 σ	≈ 2	very low

Table 2. Standards of functional preparedness for women of 25-35 years of the Podilsk region (Ukraine)

The level of development of the indicator	Indicators of aerobic productivity alactatic		Indicators of anaerobic productivity		
			alactatic	lactatic	
	VO_{2max} (ml·min·kg^{-1})	TAM (W·kg^{-1})	WAnT10 (kg·min^{-1}·kg^{-1})	WAnT 30 (kg·min^{-1}·kg^{-1})	MQMK (kg·min^{-1}·kg^{-1})
Very high	> 48.2	> 2.8	> 47.06	> 44.24	> 31.9
High	45.1 – 48.2	2.7 – 2.8	42.69 – 47.06	39.33 – 44.24	28.2 – 31.9
Above average	43.5 – 45.0	2.5 – 2.6	40.50 – 42.68	36.87 – 39.32	26.4 – 28.1
Average	43.4 – 40.3	2.4 – 2.2	40.49 – 36.11	36.86 – 31.94	26.3 – 22.6
Below average	40.2 – 38.8	2.1 – 2.0	36.10 – 33.92	31.93 – 29.48	22.5 – 20.7
Low	38.7 – 35.6	1.9 – 1.8	33.91 – 29.54	29.47 – 24.56	20.6 – 16.9
Very low	< 35.6	< 1.8	< 29.54	< 24.56	< 16.9

Note: TAM - threshold of anaerobic metabolism; WAnT10 - Wingate anaerobic test for 10 seconds; WAnT30 - Wingate anaerobic test for 30 seconds; MQMK - maximum quantity of mechanical work for 1 minute.

Table 3. Model of functional preparedness of women 25-35 years of endomorphic somatotype

Indicators	Evaluation criteria						
	very low	low	below average	average	above average	high	very high
VO_{2max}(ml·min·kg^{-1})	< 35.6	35.6 – 38.7	38.8 – 40.2	40.3 – 43.4	43.5 – 45.0	45.1 – 48.2	> 48.2
TAM (W·kg^{-1})	< 1.8	1.8 – 1.9	2.0 – 2.1	2.2 – 2.4	2.5 – 2.6	2.7 – 2.8	> 2.8
MQMK (kg·min^{-1}·kg^{-1})	< 16.9	16.9 – 20.6	20.7 – 22.5	22.6 – 26.3	26.4 – 28.1	28.2 – 31.9	> 31.9
WAnT 30 (kg·min^{-1}·kg^{-1})	< 24.56	24.56 – 29.47	29.48 – 31.93	31.94 – 6.86	36.87 – 39.32	39.33 – 44.24	> 44.24
WAnT10 (kg·min^{-1}·kg^{-1})	< 29.54	29.54 – 33.91	33.92 – 36.10	36.11 – 40.49	40.50 – 42.68	42.69 – 47.06	> 47.06

Note. The model zone for women of endomorphic somatotype is within the range of the highlighted cell–

Table 4. Model of functional preparedness of women 25-35 years of ectomorphic somatotype

Indicators	Evaluation criteria						
	very low	low	below average	average	above average	high	very high
VO_{2max}(ml·min·kg^{-1})	< 35.6	35.6 – 38.7	38.8 – 40.2	40.3 – 43.4	43.5 – 45.0	45.1 – 48.2	> 48.2
TAM (W·kg^{-1})	< 1.8	1.8 – 1.9	2.0 – 2.1	2.2 – 2.4	2.5 – 2.6	2.7 – 2.8	> 2.8
MQMK (kg·min^{-1}·kg^{-1})	< 16.9	16.9 – 20.6	20.7 – 22.5	22.6 – 26.3	26.4 – 28.1	28.2 – 31.9	> 31.9
WAnT 30 (kg·min^{-1}·kg^{-1})	< 24.56	24.56 – 29.47	29.48 – 31.93	31.94 – 36.86	36.87 – 39.32	39.33 – 44.24	> 44.24
WAnT10 (kg·min^{-1}·kg^{-1})	< 29.54	29.54 – 33.91	33.92 – 36.10	36.11– 40.49	40.50 – 42.68	42.69 – 47.06	> 47.06

Note. The model zone for women of ectomorphic somatotype is within the range of the highlighted cell –

Table 5. Model of functional preparedness of women 25-35 years of endomorphic-mesomorphic somatotype

Indicators	Evaluation criteria						
	very low	low	below average	average	above average	high	very high
VO_{2max}(ml·min·kg^{-1})	< 35.6	35.6 – 38.7	38.8 – 40.2	40.3 – 43.4	43.5 – 45.0	45.1 – 48.2	> 48.2
TAM (W·kg^{-1})	< 1.8	1.8 – 1.9	2.0 – 2.1	2.2 – 2.4	2.5 – 2.6	2.7 – 2.8	> 2.8
MQMK (kg·min^{-1}·kg^{-1})	< 16.9	16.9 – 20.6	20.7 – 22.5	22.6 – 26.3	26.4 – 28.1	28.2 – 31.9	> 31.9
WAnT 30 (kg·min^{-1}·kg^{-1})	< 24.56	24.56 – 29.47	29.48 – 31.93	31.94 – 36.86	36.87 – 39.32	39.33 – 44.24	> 44.24
WAnT10 (kg·min^{-1}·kg^{-1})	< 29.54	29.54 – 33.91	33.92 – 36.10	36.11 – 40.49	40.50 – 42.68	42.69 – 47.06	> 47.06

Note. The model zone for women of endomorphic-mesomorphic somatotype is within the range of the highlighted cell –

Table 6. Model of functional preparedness of women 25-35 years of balanced somatotype

Indicators	Evaluation criteria						
	very low	low	below average	average	above average	high	very high
VO_{2max}(ml·min·kg^{-1})	< 35.6	35.6 – 38.7	38.8 – 40.2	40.3 – 43.4	43.5 – 45.0	45.1 – 48.2	> 48.2
TAM (W·kg^{-1})	< 1.8	1.8 – 1.9	2.0 – 2.1	2.2 – 2.4	2.5 – 2.6	2.7 – 2.8	> 2.8
MQMK (kg·min^{-1}·kg^{-1})	< 16.9	16.9 – 20.6	20.7 – 22.5	22.6 – 26.3	26.4 – 28.1	28.2 – 31.9	> 31.9
WAnT 30 (kg·min^{-1}·kg^{-1})	< 24.56	24.56 – 29.47	29.48 – 31.93	31.94 – 36.86	36.87 – 39.32	39.33 – 44.24	> 44.24
WAnT10 (kg·min^{-1}·kg^{-1})	< 29.54	29.54 – 33.91	33.92 – 36.10	36.11 – 40.49	40.50 – 42.68	42.69 – 47.06	> 47.06

Note. The model zone for women of balanced somatotype is within the range of the selected cell –

productivity of the body (WAnT 30, WAnT10) (table 5).

For women of balanced somatotype is characterized by the absence of high and low levels of functional preparedness (table 6).

Thus, it was found that women of different somatotypes differ in the level of development of energy supply of muscular activity.

Discussion

In the scientific literature published several versions of standards for indicators of functional preparedness for different countries [4,7]. But in these publications, the authors do not disclose what methodology they used to develop standards. The method used by us is based on the fact that the "average" level will correspond to about 34.0% of all values; levels "below average" and "above average" - about 17%; "high" and "low" level - about 13%; "very high" and "very low" levels - about 2% (see Table 1). In our opinion, this approach provides an objective assessment.

Comparing our standards with those of other authors, we found some differences. Thus Gerald F. Fletcher et al. [4] published updated standards for maximum oxygen consumption for the American Heart Association. According to their data, the norm of $VO_{2max\ rel.}$ for women 20-29 years there is a range of 36.0 ± 6.9 ml·min·kg^{-1}, and for women 30-39 years - 34.0 ± 6.2 ml·min·kg^{-1}. Such data differ significantly from the data obtained by us. In our opinion, there are several reasons for this. The authors combined into one category of persons aged 30-39 years, which in our opinion is impractical. According to Solodkov and Sologub [27], at the age of 35 involutionary processes in the body begin to predominate. Accordingly, VO_{2max} in women 36-39 years will be lower than in women 30-35 years. In addition, lower VO_{2max} standards for women in the United States may be associated with obesity in a significant percentage of the adult population. According to Ashleigh L. May [28], the percentage of obese people in the United States increased from 13% in 1960 to 36% in 2009. Regional differences also have an important influence, as O. Dulo points out in his works [29].

In addition to the VO_{2max} standards published in the scientific literature, there are several regulatory tables that are additions to training programs and additions to the instructions for electronic GPS devices for sports (including the Garmin Race Predictor). Such data have significant differences. In particular, the norm for women 25-35 years according to some data is 33-34 ml·min·kg^{-1}, and according to others - 38-40 ml·min·kg^{-1}. However, these appendices do not specify the authors of the criteria and the method by which they were developed.

W Larry Kenney et al. [8] note that information on functional preparedness only in terms of aerobic performance is incomplete. We did not find any standards of functional preparedness for the whole spectrum of energy supply modes of muscular activity (aerobic, anaerobic lactatic and anaerobic alactatic). There are studies where Ramírez-Vélez Robinson et al. [30] determined anaerobic productivity rates for Colombian adults. But the authors determined by WAnT 30 test other indicators, in particular PP - peak power. Therefore, it is impossible to compare such data with ours.

We have set standards of functional preparedness for girls 17-19 years of age according to indicators VO_{2max}, TAM, MQMK, WAnT 30 and WAnT 10 [13]. Furman et al. [14] developed standards of functional preparedness for women and men aged 20-22. The standards developed by us for women aged 25-35 expand the age range.

Models of functional preparedness for women of different somatotypes show significant differences in the level of functional preparedness in relation to women without consider somatotype. Therefore, when assessing functional preparedness should take into account the somatotype of the subjects. For example, if a woman of endomorphic somatotype shows a low level of $VO_{2max\ rel.}$, please keep in mind, that for endomorphs this level is the norm (Table 3). Conversely, for women of ectomorphic somatotype, the value of $VO_{2max\ rel.}$ corresponding to a high level is the norm (Table 4). Such data are confirmed by other researchers. Goran Spori et al. [18] prove the need to take into account the somatotype when assessing the professional abilities of sailors by aerobic and anaerobic tests. Kornienko et al. point to the need to take into account the somatotype by studying the anaerobic productivity of the organism. [31]. The authors note that the difference in anaerobic parameters within one age group in women of different somatotypes may be greater than the difference between men and women.

Conclusions

The author's method of developing standards allows to objectively assess the indicators of functional preparedness in women 25-35 years. The developed standards are based on modern experimental data and take into account the entire energy potential of man (aerobic, anaerobic lactatic and anaerobic alactatic). Standards of functional preparedness cannot be universal for different countries and even different regions of large countries.

Models of functional preparedness of women of different somatotypes show a significant difference from the standards set for women without consider somatotype. Somatotype should be taken into account when assessing indicators of functional preparedness. The models developed by us should be used in fitness clubs to adequately assess the physical fitness of women aged 25-35.

Acknowledgements

The authors financed the study on their own.

Conflict of interest

The authors state that there is no conflict of interest.

References

1. Ramos-Jiménez A, Chávez-Herrera R, Castro-Sosa S, Pérez-Hernández LC., Hernández Torres, Olivas-Dávila D. Body Shape, Image, and Composition as Predictors of Athlete's Performance. *Fitness Medicine*, 2016; 1(2): 19–36. https://doi.org/10.5772/65034
2. Davidson K, McNaughton L. Deep water running training and road running training improve VO_{2max} in untrained women. *J. Strength Cond. Res,* 2000; 14(2): 191– 195. https://doi.org/10.1519/00124278-200005000-00012
3. Astorino TA, Allen RP, Roberson DW, Jurancich M. Effect of High-Intensity Interval Training on Cardiovascular Function, Vo_2max, and Muscular Force. *Journal of Strength and Conditioning Research*, 2012; 26(1): 138–145. https://doi.org/10.1519/JSC.0b013e318218dd77
4. Gerald F. Fletcher, Gary J. Balady, Ezra A. Amsterdam, Bernard Chaitman, Robert Eckel, Jerome Fleg, Victor F. Froelicher, Arthur S. Leon, Ileana L. Piña, Roxanne Rodney, Denise A. Simons-Morton, Mark A. Williams, Terry BazzarreExercise Standards for Testing and Training. *American Heart Association Scientific Statements*. 2001;104:1694–1740. https://doi.org/10.1161/hc3901.095960
5. Furman YuM, Miroshnichenko VM, Drachuk SP. *Promising models of physical culture and health technologies in physical education of students of higher educational institutions*. Kyiv: Olympic literature; 2013. (In Ukrainian)
6. Apanasenko GL. *Selected articles about health*. Kiev: 2005. (In Russian)
7. Pałka MJ, Rogoziński A. Standards and predicted values of anaerobic threshold. *European Journal of Applied Physiology and Occupational Physiology*, 1986; 54: 643–646. https://doi.org/10.1007/BF00943354
8. W Larry Kenney, Jack H Wilmore, David L Costill. *Physiology of Sport and Exercise.* Human Kinetics; 2019.
9. Zupanr MF, Arata AW, Dawson LH, Wile AL, Paynz TL, Hannon ME. Wingate Anaerobic Test Peak Power and Anaerobic Capacity Classification for Male and Female Intercollesiate Athletes. *Journal of Strength and Conditioning Research*, 2009; 23(9): 2598–2604. https://doi.org/10.1519/JSC.0b013e3181b1b21b
10. Taylor NAS, Fullagar HHK, Sampson JA, Notley SR, Burley SD, Lee DS, Groeller H. Physiological employment standards for firefighters: Report 2: The physiological demands of performing physically demanding fire-fighting duties, *Journal of Occupational and Environmental Medicine*, 2015; 57(10): 1072–1082. https://doi.org/10.1097/JOM.0000000000000526
11. Carlson MJ, Jaenen SP. The development of a preselection physical fitness training program for Canadian special operations regiment applicants. *J Strength Cond Res*, 2012; 26: 2–14. https://doi.org/10.1519/JSC.0b013e31825d7ff9
12. Collingwood TR, Hoffman R, Smith J. Underlying Physical Fitness Factors for Performing Police Officer Physical Tasks. *J.Police Chief*, 2004; 71(3): 32–37.

13. Furman YuM, Miroshnichenko VM, Brezdeniuk OYu, Furman TYu. An estimation of aerobic and anaerobic productivity of an organism of youth aged 17-19 years old of Podilsk region. *Pedagogics, Psychology, Medical-Biological Problems of Physical Training and Sports*, 2018; 22(3): 136–141. https://doi.org/10.15561/18189172.2018.0304
14. Furman Iu, Miroshnichenko V, Brezdeniuk O. An Estimation of Functional Preparedness of an Organism of Youth 20-22 Years Old. *Physical Education, Sport and Health Culture in Modern Society*, 2019; 2(46): 41–47. (in Ukrainian) https://doi.org/10.29038/2220-7481-2019-02-41-47
15. Furman Iu, Brezdeniuk O, Miroshnichenko V. Estimating functional fitness of teenagers aged 11-12 years by indices of aerobic and anaerobic productivity. *Sports Medicine and Physical Rehabilitation*, 2020; 1: 40–43. (in Ukrainian) https://doi.org/10.32652/spmed.2020.1.40-43
16. Woods CT, McKeown I, O'Sullivan M, Robertson S, Davids K. Theory to Practice: Performance Preparation Models in Contemporary High-Level Sport Guided by an Ecological Dynamics Framework. *Sports Med – Open,* 2020; 6(36). https://doi.org/10.1186/s40798-020-00268-5
17. Miroshnichenko VM, Furman YM, Bohuslavska VYu, Brezdeniuk OYu, Salnykova SV, Shvets OP, Boiko MO. Functional preparedness of women of the first period of mature age of different somatotypes. *Pedagogy of Physical Culture and Sports*, 2021;25(5):232–240. https://doi.org/10.15561/26649837.2021.0504
18. Goran Spori, Daniel Bok, Dinko Vuleta Jr., Dra`en Harasin. Impact of Body Composition on Performance in Fitness Tests among Personnel of the Croatian Navy. *Coll. Antropol.,* 2011; 35(2): 335–339.
19. Zimnitskaya R, Paramonova N, Jakubovskii D. Comparative analysis of functional state and working capacity on veloergometer of average training level women of age. *Sporto Mokslas*, 2017; 1(87): 32–37. https://doi.org/10.15823/sm.2017.5
20. Ryan-Stewart H, Faulkner J, Jobson S. The influence of somatotype on anaerobic performance. Barbosa TM (ed.) *PLOS ONE*. 2018;13(5): e0197761. https://doi.org/10.1371/journal.pone.0197761
21. Karpman VL, Gudkov IA, Koydikova GA. Indirect determination of maximum oxygen consumption of highly skilled athletes. *Theory and Practice of Physical Culture*, 1972; 1: 37–41. (in Russian)
22. Mackenzie B. PWC-170 Cycle Test. *Brianmac Sports Coache*, 2002: [updated 2021 Jul 8; cited 2022 Feb 23]. Available from: https://www.brianmac.co.uk/pwc170.htm
23. Conconi F, Ferrari M, Ziglio PG, Droghetti P, Codeca L. Determination of anaerobic threshold by a noninvasive field test in runners. *J. Appl. Physiol*, 1982; 52: 869–873. https://doi.org/10.1152/jappl.1982.52.4.869
24. Szögÿ A, Cherebeţiu G. Minutentest auf dem Fahrradergometer zur Bestimmung der anaeroben Kapazität [Minute test on the bicycle ergometer to determine anaerobic capacity]. *European Journal of Applied Physiology and Occupational Physiology*. 1974;33(2): 171–176. (In German) https://doi.org/10.1007/BF00449517
25. Bar-Or O. The Wingate anaerobic test: An update on methodology, reliability and validity. *Sports Medicine,* 1987; **4:** 381–394. https://doi.org/10.2165/00007256-198704060-00001
26. Carter J, Heath B. *Somatotyping – development and applications*. Cambridge University Press; 1990.
27. Solodkov AS, Sologub EB. *Human physiology. General. Sports. Age.* Moscow: Olimpiia Press; 2005. (In Russian)
28. May AL, Freedman D, Sherry B, Blanck HM. Obesity – United States, 1999–2010. *National Center for Chronic Disease Prevention and Health Promotion*, 2013;62(03):120–128.
29. Dulo OA, Furman UM. Comparative characteristics of aerobic productivity of girls with different somatotypes living in mountainous and lowland areas of Transcarpathia. *Biomedical and Biosocial Anthropology*, 2013; 20: 23–27. (in Ukrainian)
30. Ramírez-Vélez Robinson, López-Albán Carlos A., La Rotta-Villamizar Diego R., Romero-García Jesús A., Alonso-Martinez Alicia M., Izquierdo Mikel. Wingate Anaerobic Test Percentile Norms in Colombian Healthy Adults. *The Journal of Strength & Conditioning Research*, 2016; 30(1): 217–225. https://doi.org/10.1519/JSC.0000000000001054
31. Kornienko I, Son'kin V, Tambovtsev R, Panasyuk T. Development of the Energetics of Muscular Exercise with Age: Summary of a 30-Year Study: IV. The Development of the Energetics of Skeletal Muscles Depending on the Somatotype. *Human Physiology*, 2007; 33(6): 742–746. https://doi.org/10.1134/s036211970706012

Information about the authors:

Yuriy M. Furman; https://orcid.org/0000-0002-5206-7712; furman-dok@ukr.net; Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University; Vinnytsia, Ukraine.

Viacheslav M. Miroshnichenko; (Corresponding author); https://orcid.org/0000-0003-1139-4554; 29miroshnichenko@gmail.com; Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University; Vinnytsia, Ukraine.

Viktoriia Yu. Bohuslavska; https://orcid.org/0000-0003-3609-5518; Vik.bogusl@gmail.com; Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University; Vinnytsia, Ukraine.

Natalia V. Gavrylova; https://orcid.org/0000-0001-6209-5875; gavrilova.natal83@gmail.com; Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University; Vinnytsia, Ukraine.

Olexsandra Yu. Brezdeniuk; http://orcid.org/0000-0003-0844-8777; sandrikk86@gmail.com; Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University; Vinnytsia, Ukraine.

Svitlana V. Salnykova; https://orcid.org/0000-0003-4675-6105; aqvasveta@ukr.net; Vinnytsia Institute of Trade and Economics of Kyiv National University of Trade and Economics; Vinnytsia, Ukraine.

Viktoria V. Holovkina; http://orcid.org/0000-0001-9912-7754; akvavita72@gmail.com; Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University; Vinnytsia, Ukraine.

Igor P. Vypasniak; https://orcid.org/0000-0002-4192-1880; ihor.vypasniak@pnu.edu.ua; Department of Theory and Methods of Physical Culture; Vasyl Stefanyk Precarpathian National University; Ivano-Frankivsk, Ukraine.

Vasyl Y. Lutskyi; https://orcid.org/0000-0003-3940-1349; luckij55@gmail.com; Department of Theory and Methods of Physical Culture; Vasyl Stefanyk Precarpathian National University; Ivano-Frankivsk, Ukraine.

Cite this article as:
Furman YM , Miroshnichenko VM, Boguslavska VYu, Gavrilova NV , Brezdeniuk OYu, Salnykova SV , Holovkina VV, Vypasniak IP, Lutskyi VY. Modeling of functional preparedness of women 25-35 years of different somatotypes. *Pedagogy of Physical Culture and Sports*, 2022;26(2):118–125.
https://doi.org/10.15561/26649837.2022.0206

Received: 20.01.2022
Accepted: 06.04.2022; Published: 30.04.2022

ORIGINAL ARTICLE

Evaluation and comparative analysis of the results of a vertical jump between young basketball and handball players

Nikola Aksović[1ABDE], Bojan Bjelica[2ACD], Filip Milanović[3ACD], Borislav Cicović[2DE], Saša Bubanj[1ACD], Dejan Nikolić[4,5BCD], Iryna Skrypchenko[6ADE], Victor Rozhechenko[6ADE], Milan Zelenović[2BCD]

[1]*Faculty of Sport and Physical Education, University of Niš, Serbia*
[2]*Faculty of Physical Education and Sport, University of East Sarajevo, Bosnia and Herzegovina*
[3]*Orthopedic Surgery and Traumatology Department, University Children's Hospital, Belgrade, Serbia*
[4]*Faculty of Medicine, University of Belgrade, Serbia*
[5]*Physical Medicine and Rehabilitation Department, University Children's Hospital, Belgrade, Serbia*
[6]*Department of Physical Education & Tactical and Special Training, Dnipropetrovsk State University of Internal Affairs, Ukraine*

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; ; E – Funds Collection

Abstract

Background and Study Aim — Team sports, basketball and handball, as well as their competitions, are very popular throughout the world. The aim of this research was evaluation and comparative analysis of the results of a vertical jump between young basketball and handball players.

Material and Methods — A group of 37 participants took part in the research: 21 basketball players from the basketball club OKK ''Novi Pazar'' (age: 15.5 ± 0.5) from Novi Pazar formed the first subgroup and 16 handball players from the handball club RK ''Železničar 1949'' (age: 25.4 ± 5.8; body height = 193.5 ± 7.5 cm; body weight = 94.0 ± 7.4 kg; body mass index = 25.03 ± 2.38 kg/m2) from Niš formed the second subgroup. Explosive power of the vertical jumps was assessed by the following tests: countermovement jump, countermovement jump/arm swing, squat jump. Participants had at least 5 years of training experience and held similar acute training histories prior to study commencement, completing 4 weeks of baseline conditioning during the general preparatory phase. Participants were free of injury, illness and disease as determined by a team physician prior to study participation.

Results — The results of the independent samples t-test show that there were no significant differences ($p > 0.05$) between basketball and handball players in all vertical jump tests.

Conclusions — This article contains new information about vertical jumps of young male basketball and elite male handball players that could be extremely useful for coaches. Also, these findings suggest that basketball coaches may benefit from talents' identification in young basketball players.

Keywords: team sports, explosive power, lower limbs, jumping performance, differences

Introduction

Team sports, basketball and handball, as well as their competitions, are very popular throughout the world. Success in these sports depends on several anthropological dimensions, whose relationships are different. Thanks to the very intensive development of technique and tactics in recent years, both these sports games have become very complex and demanding. Basketball and handball are characterized by similar movement structures, such as a constant change in the phase of attack and defense, rapid changes in the direction of movement, sudden stops and dribbles, as well as a large number of jumps in attack and defense. However, there are differences and specifics in the structure of each sports game, such as different rules of the game, duration of the match, number and position of players on the field, different structure of certain types of movement in attack and defense, etc. [1].

Explosive power, often assessed as vertical jump, is a foundational component of vital movements [2, 3] in many collective sports [4, 5], such as rugby, volleyball, basketball, handball and soccer [6-10]. Basketball and handball are characterized by explosive, unilateral actions such as jumping [11] and has been considered as fundamental for successful performance [12] in these sports. Since vertical jumps are the predominant elements of the game in both sports, their successful realization depends on the explosive power of the lower limbs. Vertical jumps are used when players make certain important technical acts such as the shot in basketball [13, 14] or the shot or block in handball, which require not only a high jump but also the correct direction of forces of the upper limb in order to try blocking the opponent's shot. In fact, a greater jump height achieved during a jump in basketball

doi:10.15561/26649837.2022.0207

produces more favourable condition for shots and rebounds [12], while in handball the achievement of a greater jump height provides a clear advantage in the attack and block actions. The following factors can also affect the characteristics of vertical jumps in basketball and handball: the trajectory of the ball, the skill level of the players, body contact with surrounding players, or the type of action performed (offensive or defensive). These factors make each jump a relatively different task [15].

Numerous studies have shown the importance of vertical jumps in young elite male basketball players [15-19, 20, 21]. The explosive power in the form of vertical jumps is a significant characteristic of basketball players, and it is one of the most important factors in achieving top sports results [22, 23]. During the game, basketball players spend 34% of their time running and jumping, 56.8% walking, 9% of their time standing and changing their form or intensity of movement on average every 2 seconds [24]. Also, in basketball, the vertical jumps dominate because of facilitating the realization of specific technical and tactical elements[1, 25].

Several original studies [26-30, 31] showed the importance of jumping ability in elite male handball players. Also, it should be emphasized that explosive power of throwing type is particularly important for success in handball [26]. The success of vertical jumps is determined by the velocity at take-off [31]. As it is well known, handball and basketball studies have used standardized jump tests from a standing position using a 2-legged take-off (i.e., vertical countermovement jump with and without an arm swing, squat jump [29]. Therefore, vertical jumps are considered as an essential motor skill in a range of team sports, including basketball [32] and handball [33]. However, is not known if there are differences in vertical jumps between young basketball players and senior handball players. Thus, it is expected that there are differences in vertical jumps, in favor of handball players, and the key factors that contribute to the confirmation of this hypothesis are biological maturity, the skill level of players and age players.

Therefore, the aim of this research was to evaluation and comparative analysis of the results of a vertical jump between young basketball and handball players.

Material and Methods

Participants

A group of 37 participants took part in the research. They were divided into two subgroups: 21 young elite male basketball players from the basketball club OKK ''Novi Pazar'' (age: 15.5 ± 0.5; body height = 185.15 ± 7.13 cm; body weight = 75.14 ± 11.91 kg; body mass index = 21.93 ± 2.90 kg/m^2) from Novi Pazar formed the first subgroup and 16 elite male handball players from the handball club RK ''Železničar 1949'' (age: 25.4 ± 5.8; body height = 193.5 ± 7.5 cm; body weight = 94.0 ± 7.4 kg; body mass index = 25.03 ± 2.38 kg/m^2) from Niš formed the second subgroup. Participants had at least 5 years of training experience and held similar acute training histories prior to study commencement, completing 4 weeks of baseline conditioning during the general preparatory phase. Participants were free of injury, illness and disease as determined by a team physician prior to study participation. All participants were informed of the study aims and gave informed written consent to participate prior to testing. Based on the average values of body mass index we can say that our participants are among the elite population of young basketball and handball players. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the Ethics Committee of the Faculty of Sport and Physical Education before commencement.

Research Design

Prior to physical performance testing, participants completed a standardised warm-up consisting of moderate intensity jogging (8 min), static stretching (5 min) and brief bouts of high-intensity running (2 min). To assess the anthropometric characteristics, the following were: body height (BH), body mass (BM) and body mass index (BMI) were calculated. Data on the anthropometric measures were not subjected to statistical analysis and were used to describe the sample of participants. Explosive power of the vertical jumps was assessed by the following tests: countermovement jump (CMJ), countermovement jump/arm swing (CMJAS), squat jump (SJ). All jumps were performed on a photocell mat (Optojump, Microgate, Bolzano, Italy) which measures flight time between take-off and subsequent landing to calculate jump height (cm). Validity and reliability of the Optojump system has been confirmed in previous research [34]. Each trial was validated by a visual inspection to ensure that each landing was performed without any leg flexion; furthermore, participants were instructed to maintain their hands on their hips during the CMJ and squat jump and to use the arm swing in the CMJAS. The CMJ (with and without an arm swing) was performed starting from a standing position after which participants were asked to jump as high as possible with a rapid, preparatory downward eccentric action. The depth of the CMJ was self-selected. Participants performed the squat jump starting from a standing position, bending the knees to 90°, stopping for 3 s, and then jumping as high as possible to avoid any knee or trunk countermovement. Each test was performed three times, separated by 1 min of passive recovery, and the best jump was recorded and used for analysis. Participants were wearing athletic shoes during all jumps.

Statistical analysis

Data processing used basic descriptive parameters: range (Range), minimum value (Min), maximum value (Max), arithmetic mean (Mean), Standard deviation (SD), rate asymmetry (Skewness and Kurtosis). The t-test (independent samples test) was used for comparison between the two groups of participants. The magnitude of difference between basketball and handball players was measured using effect size (ES) and interpreted using previously established criteria: *trivial* = <0.20; *small* = 0.2–0.59; *moderate* = 0.60–1.19; *large* = 1.20–1.99; *very large* = > 2.0 [35]. The statistical significance was set at the level of p<0.05. All statistical analyses were performed using SPSS 19.0 software (SPSS Inc., Chicago, IL).

Results

Descriptive parameters for basketball and handball players are shown in Tables 1 and 2. By examining the tables and comparing the results of Standard Deviation (SD), with maximal range (Max) and minimal (Min), the normal sensibility of chosen tests was concluded.

With the group of young basketball players shown in Table 1, the values of Skewness show that there are no significant deviations of the results from the normal distribution in any of the measures, considering that the values do not exceed 1.00 in any of the variables. The Kurtosis values in all variables are below 2.75, which indicates platykurtic distribution.

The analysis of the basic statistical parameters of the vertical jumps among handball players shown in Table 2 indicates that Skewness show that there are no significant deviations of the results from the normal distribution in any of the measures, considering that the values do not exceed 1.00 in any of the variables. The Kurtosis values in all variables are below 2.75, which indicates platykurtic distribution.

Table 3 indicates the vertical jumps characteristics of basketball and handball players and results of the comparison between these two groups of players (t-test). Levene's Test of Equality of Error Variances have shown that the assumption of equality of the variance was not violated (p<0.05). There were no significant differences (p>0.05) between basketball and handball players in all vertical jump tests (CMJ, CMJAS, and SJ). *Trivial* ES differences between basketball and handball players were observed in CMJ (ES = 0.09), CMJAS (ES = 0.09), and SJ (ES = 0.08).

Table 1. The basic statistical parameters of the vertical jumps in basketball players

Variables	N	Range	Min	Max	Mean	SD	Skewness	Kurtosis
CMJ	21	20.10	21.30	41.40	32.06	5.40	-.335	-.299
CMJAS	21	25.50	25.00	50.50	38.54	6.98	.025	-.110
SJ	21	20.40	20.00	40.40	30.95	5.11	-.253	-.146

Note: number of participants (N), range (Range), minimum (Min), maximum (Max), arithmetic mean (Mean), standard deviation (SD), Skewness (Skewness), Kurtosis (Kurtosis), countermovement jump (CMJ), countermovement jump/arm swing (CMJAS), squat jump (SJ).

Table 2. The basic statistical parameters of the vertical jumps in handball players

Variables	N	Range	Min	Max	Mean	SD	Skewness	Kurtosis
CMJ	16	15.80	24.90	40.70	32.10	4.32	.526	-.037
CMJAS	16	17.80	28.40	46.20	38.00	4.51	-.222	.294
SJ	16	11.90	25.00	36.90	30.54	3.97	.416	-.942

Note: number of participants (N), range (Range), minimum (Min), maximum (Max), arithmetic mean (Mean), standard deviation (SD), Skewness (Skewness), Kurtosis (Kurtosis), countermovement jump (CMJ), countermovement jump/arm swing (CMJAS), squat jump (SJ).

Table 3. Means ± standard deviation of all variables for basketball and handball players and the comparison between these two groups (results of independent samples t-test).

Variables	Basketball Players	Handball Players	t	p	ES	Magnitude
CMJ	32.06 ± 5.40	32.10 ± 4.32	-0.27	.979	0.09	Trivial
CMJAS	38.54 ± 6.98	38.00 ± 4.51	.264	.794	0.09	Trivial
SJ	30.95 ± 5.11	30.54 ± 3.97	.259	.797	0.08	Trivial

Note: countermovement jump (CMJ), countermovement jump/arm swing (CMJAS), squat jump (SJ), the value of the differences between young basketball and handball players (t), statistical significance of differences (p<0.05), effect size (ES), Magnitude-based inferences (Magnitude).

Discussion

The primary purposes of this study was to evaluation and comparative analysis of the results of a vertical jump between young basketball and handball players. Results of this study have shown that there were no significant differences between basketball and handball players in all vertical jump tests (CMJ, CMJAS, and SJ). *Trivial* differences were evident across all vertical jump tests. It was hypothesized that there were differences in vertical jumps between young elite male basketball and elite male handball players. Surprisingly, our hypothesis not accepted. These results were not expected, and the reason for that can be an age, genetic predisposition, the average values of BMI, and the skill level of players. The age of participants is one of the most important components. The most sensitive factor of given results is age, since the training of young basketball players mustn't be based on the principles that training for adults is based on. It has to be in compliance with their biological, chronological, psychological and physical growth.

There are several explanations for these results. The obtained results can be justified by the fact that the technical and tactical basketball trainings, as well as basketball matches, involve a large number of vertical jumps with both legs both in attack and defense. In basketball, the jump in attack and defense is performed with maximum vertical reflection, which is not the case in handball. The exception is when the basketball players perform a jump from the movement after the bounced ball or when performing a shot on the basket from the movement, then they perform with a stronger leg. It is similar with handball players, when taking a shot on goal from the move, they perform with a stronger leg. In addition to the tests used in this study, a vertical single leg countermovement jump may have been required. This would be interesting, because in that way we would have a clearer ratio of vertical jumps from one and both legs in young basketball players and handball players.

The significance of vertical jumps in basketball is also confirmed [25] with the fact that one basketball match consists of (46 ± 12) jumps per one player [36, 37], i.e. a basketball player performs up to 100 different jumps in a game [38]. During half an hour the player jumps about (16-17) times, and when we count it, we get 35 times during the whole match [39]. The importance of vertical jumps for basketball is also indicated by the fact that better placed national teams, at the 2006 World Cup in Japan, successfully catch bounced balls under the opponent's basket - jump in attack [40]. In handball, vertical jumps are also crucial [26, 31, 41, 42], but this sport is also characterized by a large number of horizontal jumps. Results of this study have shown that throwing is one of the most important technical skills in modern handball as it is the major determinant of all actions taken by the players. The of research Bojić et al. [1] points to an importance of vertical and horizontal jumps in handball such as: shooting past the block, defence blocking, shooting while getting into the goalkeeper's line from different players' positions. Results of this study have shown that basketball players achieved statistically better results in vertical jump tests, whereas handball players did better in horizontal jump tests. Similar results were found in a study of [43] which have shown that male basketball players achieved better results in vertical jump tests (SJ and CMJ) as compared to male handball players. In contrast, Peña et al. [44] have shown that there were no significant differences in vertical jumps between basketball and handball players. Furthermore, volleyball players have shown significantly better results than basketball and handball players in CMJ and CMJAS jumps, while in SJ test there was no difference between the groups. It would be interesting to examine the differences in horizontal jumps on the same or a similar sample of participants, or to examine the differences in vertical jumps after applying an experimental program (for example plyometric or resistance training) which is a recommendation to future researchers on this or similar topic.

Comparison between our results and those made previously are difficult to conduct, considering the lack of existing researches in young elite male basketball and elite male handball players. Previous studies [1, 43, 44] had groups of the same or similar age for the sample, which was not the case in this study. Our findings were obtained in young male basketball players, and senior male handball players and it is questionable whether the present results for the examined tests hold true for female samples. Therefore, the comparison of our study with the above should be viewed in the context of relevant limitations. Therefore, this article contains new information about vertical jumps of young elite male basketball players and elite male handball players that could be extremely useful for coaches. Also, these findings suggest that basketball coaches may benefit from talents` identification in young basketball players. In addition, our results could be incorporated into a database according to which talented young basketball players could be compared.

Despite interesting outcomes in this study, some important limitations should be acknowledged. Firstly, basketball players were tested in the evening (20:00-21:30 h) and handball players in the morning (8:00-9:30 h). It is well known that there are morning-to-evening differences in physical performance with and without ball in elite male handball players [29]. Future studies should identify if training administered in the morning can reduce morning-to-evening differences in basketball players. Secondly, limitation of the study was relatively small sample size (n=37). However, to make the differences in vertical jumps clearer, an effect size (ES) was calculated for each variable. Thirdly, although our findings provide valuable insight into young elite male basketball and elite male handball players, the applicability of these results remains limited to other ages, playing levels and females. Fourthly, handball is very complex sports activity, where successful performance particularly depends on explosive strength (of throwing type) and basic strength of the trunk [26, 45], while in basketball the most important is the explosive power of vertical jumping.

Conclusions

The present study, despite its limitations, revealed that there were no differences in vertical high jump tests between young elite male basketball players and elite male handball players. This article contains new information about vertical jumps of young male basketball and elite male handball players that could be extremely useful for coaches. Also, these findings suggest that basketball coaches may benefit from talents' identification in young basketball players. Thus, more research is needed to examine vertical jumps among young basketball players and handball players.

Highlights

No differences in vertical high jump tests (CMJ, CMJAS, SJ) between young elite male basketball players and elite male handball players.

Funding

No funds were provided.

Conflicts of interest

All authors have no conflicts of interest.

References

1. Bojić I, Kocić M, Stajić S. The explosive power of the lower limbs in basketball and handball players. *Facta Universitatis, Series: Physical Education and Sport*, 2015; 13(1): 1–9.
2. Vila H, Manchado C, Rodriguez N, Abraldes JA, Alcaraz PE, Ferragut C. Anthropometric profile, vertical jump, and throwing velocity in elite female handball players by playing positions. *The Journal of Strength & Conditioning Research*, 2012; 26(8): 2146–2155. https://doi.org/10.1519/JSC.0b013e31823b0a46
3. Dobbs WC, Tolusso DV, Fedewa MV, Esco MR. Effect of post activation potentiation on explosive vertical jump: a systematic review and meta–analysis. *The Journal of Strength & Conditioning Research*, 2019; 33(7): 2009–2018. https://doi.org/10.1519/jsc.0000000000002750
4. Stojanović E, Ristić V, McMaster DT, Milanović Z. Effect of plyometric training on vertical jump performance in female athletes: a systematic review and meta-analysis. *Sports Medicine*, 2017; 47(5): 975–986. https://doi.org/10.1007/s40279-016-0634-6
5. Zelenović M, Bjelica B, Lučić S, Đorđević D. The impact of plyometric training on explosive strength in sports. *VII International Scientific Conference „Anthropological and teo-anthropological views on physical activity from the time of Constantine the Great to modern times"*, 2020; 24–32.
6. McMahon J, Lake JP, Ripley N, Comfort P. Vertical jump testing in rugby league: a rationale for calculating take-off momentum. *Journal of Applied Biomechanics*, 2020; 14: 1–5. http://doi.org/10.1123/jab.2020-0100
7. Şahin E, Özdal M. Effect of core exercises on balance and vertical jump of 12-14 aged female volleyball players. *European Journal of Physical Education and Sport Science*, 2020; 6(4): 47–54.
8. Heishman AD, Daub BD, Miller RM, Freitas ED, Frantz BA, Bemben MG. Countermovement jump reliability performed with and without an arm swing in NCAA division 1 intercollegiate basketball players. *The Journal of Strength & Conditioning Research*, 2020; 34(2): 546–558. http://doi.org/10.1519/JSC.0000000000002812
9. Ozmen T, Aydogmus M, Yana M, Simsek A. Effect of core strength training on balance, vertical jump height and throwing velocity in adolescent male handball players. *The Journal of Sports Medicine and Physical Fitness*, 2020; 60(5): 693–699. https://doi.org/10.23736/S0022-4707.20.10382-7
10. Katushabe ET, Kramer M. Effects of combined power band resistance training on sprint speed, agility, vertical jump height and strength in collegiate soccer players. *International Journal of Exercise Science*, 2020; 13(4): 950–963.
11. Fort-Vanmeerhaeghe A, Gual G, Romero-Rodriguez D, Unnitha V. Lower limb neuromuscular asymmetry in volleyball and basketball players. *Journal of Human Kinetics*, 2016; 50(1): 135–143. https://doi.org/10.1515/hukin-2015-0150
12. Makaruk H, Starzak M, Suchecki B, Czaplicki M, Stojiljković N. The effects of assisted and resisted plyometric training programs on vertical jump performance in adults: a systematic review and meta-analysis. *Journal of Sports Science & Medicine*, 2020; 19(2): 347.
13. Battaglia G, Paoli A, Bellafiore M, Bianco A, Palma A. Influence of a sport-specific training background on vertical jumping and throwing performance in young female basketball and volleyball players. *Journal of Sports Medicine and Physical Fitness*, 2014; 54(5): 581–587.
14. Shalfawi SA, Sabbah A, Kailani G, Tønnessen E, Enoksen E. The relationship between running speed and measures of vertical jump in professional basketball players: a field-

test approach. *The Journal of Strength & Conditioning Research*, 2011; 25(11): 3088–3092. https://doi.org/10.1519/JSC.0b013e318212db0e
15. Rodríguez-Rosell D, Mora-Custodio R, Franco-Márquez F, Yáñez-García JM, González-Badillo JJ. Traditional vs. sport-specific vertical jump tests: reliability, validity, and relationship with the legs strength and sprint performance in adult and teen soccer and basketball players. *The Journal of Strength & Conditioning Research*, 2017; 31(1): 196–206. https://doi.org/10.1519/JSC.0000000000001476
16. Gonzalo-Skok O, Serna J, Rhea MR, Marín PJ. Relationships between functional movement tests and performance tests in young elite male basketball players. *International Journal of Sports Physical Therapy*, 2015; 10(5): 628–638.
17. Adigüzel NS, Günay M. The effect of eight weeks plyometric training on anaerobic power, counter movement jumping and isokinetic strength in 15-18 years basketball players. *International Journal of Environmental and Science Education*, 2016; 11(10): 3241–3250.
18. Paz GA, de Freitas Maia M, Farias D, Santana H, Miranda H, Lima V, Herrington L. Kinematic analysis of knee valgus during drop vertical jump and forward step-up in young basketball players. *International Journal of Sports Physical Therapy*, 2016; 11(2): 212.
19. Stevanovic VB, Jelic MB, Milanovic SD, Filipovic SR, Mikic MJ, Stojanovic MD. Sport-specific warm-up attenuates static stretching-induced negative effects on vertical jump but not neuromuscular excitability in basketball players. *Journal of Sports Science & Medicine*, 2019; 18(2): 282.
20. Gül M, Gül KG, Ataç Ö. The effect of plyometric trainings on vertical-horizontal jump and some motor skills in U13 basketball players. *Journal of Education and Training Studies*, 2019; 7(7): 71–78. https://doi.org/10.11114/jets.v7i7.4252
21. Della Corte J, Pereira WLM, Corrêa EELS, de Oliveira JGM, Lima BLP, deCastro JBP, Lima VP. Influence of power and maximal strength training on thermal reaction and vertical jump performance in Brazilian basketball players: a preliminary study. *Biomedical Human Kinetics*, 2020; 12(1), 91–100. https://doi.org/10.2478/bhk-2020-0012
22. Cortis C, Tessitore A, Lupo C, Pesce C, Fossile E, Figura F, Capranica L. Inter-limb coordination, strength, jump, and sprint performances following a youth men's basketball game. *The Journal of Strength & Conditioning Research*, 2011; 25(1): 135–142. https://doi.org/10.1519/JSC.0b013e3181bde2ec
23. Domínguez-Díez M, Castillo D, Raya-González J, Sánchez-Díaz S, Soto-Célix M, Rendo-Urteaga T, Lago-Rodríguez Á. Comparison of multidirectional jump performance and lower limb passive range of motion profile between soccer and basketball young players. *Plos One*, 2021; 16(1): e0245277. https://doi.org/10.1371/journal.pone.0245277
24. Jakovljević S, Karalejić M, Pajić Z, Mandić R. Ubrzanje i brzina promene smera i načina kretanja kvalitetnih košarkaša [Acceleration and change of direction and manner of movement of quality basketball players] *Physical Culture,* 2011; 65(1): 16–23. (In Serbian). https://doi.org/10.5937/fizkul1101016J
25. Aksović N, Kocić M, Berić D, Bubanj S. Explosive power in basketball players. *Facta Universitatis, Series: Physical Education and Sport,* 2020; 18(1): 119–134. https://doi.org/10.22190/FUPES200119011A
26. Monsef Cherif MS, Chaatani S, Nejlaoui O, Gomri D, Abdallah A. The effect of a combined high-intensity plyometric and speed training program on the running and jumping ability of male handball players. *Asian Journal of Sports Medicine*, 2012; 3(1): 21. https://doi.org/10.5812/asjsm.34721
27. Carvalho A, Mourão P, Abade E. Effects of strength training combined with specific plyometric exercises on body composition, vertical jump height and lower limb strength development in elite male handball players: a case study. *Journal of Human Kinetics*, 2014; 41(1): 125–132. https://doi.org/10.2478%2Fhukin-2014-0040
28. González-Ravé JM, Juárez D, Rubio-Arias JA, Clemente-Suarez VJ, Martinez-Valencia MA, Abian-Vicen J. Isokinetic leg strength and power in elite handball players. *Journal of Human Kinetics*, 2014; 41(1): 227–233. https://doi.org/10.2478/hukin-2014-0050
29. Pavlović Lj, Stojiljković N, Aksović N, Stojanović E, Valdevit Z, Scanlan AT, Milanović Z. Diurnal variations in physical performance: Are there morning-to-evening differences in elite male handball players? *Journal of Human Kinetics*, 2018; 63(1): 117–126. https://doi.org/10.2478/hukin-2018-0012
30. Font R, Irurtia A, Gutierrez JA, Salas S, Vila E, Carmona G. The effects of COVID-19 lockdown on jumping performance and aerobic capacity in elite handball players. *Biology of Sport*, 2021; 38(4): 753. https://doi.org/10.5114/biolsport.2021.109952
31. Dello Iacono A, Martone D, Milic M, Padulo J. Vertical-vs. horizontal-oriented drop jump training: chronic effects on explosive performances of elite handball players. *Journal of Strength and Conditioning Research*, 2017; 31(4): 921–931. https://doi.org/10.1519/jsc.0000000000001555
32. Aksović N, Bjelica B, Milanović F, Jovanović N, Zelenović M. Plyometric training effects on explosive power, sprint and direction change speed in basketball. A review. *Turkish Journal of Kinesiology*, 2021; 7(2): 73–79. https://doi.org/10.31459/turkjkin.929325
33. El Araby HES. The effectiveness of using the ballistic training for developing the muscular ability on the strength and accuracy of High-jump shooting upon handball players. *World Journal of Sport Sciences*, 2010; 3: 572–577. https://doi.org/10.24042/albayan.v12i1.5775
34. Glatthorn JF, Gouge S, Nussbaumer S, Stauffacher S, Impellizzeri FM, Maffiuletti NA. Validity and reliability of Optojump photoelectric cells for estimating vertical jump height. *The Journal of Strength & Conditioning Research*, 2011; 25(2): 556–560. https://doi.org/10.1519/JSC.0b013e3181ccb18d

35. Hopkins W, Marshall S, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Medicine Science in Sports Exercise*, 2009; 41(1): 3. https://doi.org/10.1249/MSS.0b013e31818cb278
36. McInnes SE, Carlson JS, Jones CJ, McKenna MJ. The physiological load imposed on basketball players during competition. *Journal of Sports Sciences,* 1995; 13(5): 387–397. https://doi.org/10.1080/02640419508732254
37. Castagna C, Chaouachi A, Rampinini E, Chamari K, Impellizzeri F. Aerobic and explosive power performance of elite Italian regional-level basketball players. *The Journal of Strength & Conditioning Research*, 2009; 23(7): 1982–1987. https://doi.org/10.1519/JSC.0b013e3181b7f941
38. Manojlović V, Erčulj F. Impact of the focus of attention on vertical jump performance of junior basketball players. *Physical Culture*, 2013; 67(1): 61–67. https://doi.org/10.5937/fizkul1301061M
39. Narazaki K, Berg K, Stergiou N, Chen B. Physiological demands of competitive basketball. *Scandinavian Journal of Medicine & Science in Sports,* 2009; 19(3): 425–432. https://doi.org/10.1111/j.1600-0838.2008.00789.x
40. Jovanović I, Jovanović D. Stepen predikcije i eksplikacije statističkih obeležja na plasman reprezentacija na Prvenstvu sveta u košarci 2006. u Japanu. [The degree of prediction and explication of statistical features on the placement of national teams at the 2006 World Basketball Championship in Japan]. *XII International Scientific Conference „Fis Communications 2006" in Physical Education, Sport and Recreation,* 2006: 154–162. (In Serbian).
41. Dello Iacono A, Martone D, Padulo J. Acute effects of drop-jump protocols on explosive performances of elite handball players. *Journal of Strength and Conditioning Research*, 2016; 30(11): 3122–3133. https://doi.org/10.1519/JSC.0000000000001393
42. Chanev S. Normative framework for control and optimization of the physical development and specific working capacity of 17-19 year-old handball players. *Journal of Applied Sports Sciences*, 2021; 1: 22–41. https://doi.org/10.37393/JASS.2021.01.3
43. Singh B, Kumar A, Ranga MD. Comparison of vertical jump performance of male handball andbasketball players. *Journal of Exercise Science and Physiotherapy*, 2014; 10(1): 64. https://doi.org/10.18376//2014/v10i1/67502
44. Peña J, Moreno-Doutres D, Coma J, Cook M, Buscà B. Anthropometric and fitness profile of high-level basketball, handball and volleyball players. *Revista Andaluza de Medicina del Deporte*, 2018; 11(1): 30–35. https://doi.org/10.1016/j.ramd.2016.03.002
45. Carvalho A, Mourão P, Abade E.. Effects of strength training combined with specific plyometric exercises on body composition, vertical jump height and lower limb strength development in elite male handball players: a case study. *Journal of Human Kinetics*, 2014; 41(1): 125–132. https://doi.org/10.2478%2Fhukin-2014-0040

Information about the authors:

Nikola Aksović; https://orcid.org/0000-0001-8123-413X; kokir87np@gmail.com; Faculty of Sport and Physical Education, University of Niš, Serbia.

Bojan Bjelica; https://orcid.org/0000-0001-5539-8210; vipbjelica@gmail.com; Faculty of Physical Education and Sport, University of East Sarajevo, Bosnia and Herzegovina.

Filip Milanović; https://orcid.org/0000-0002-4530-998X; filipmilanovic333@gmail.com; Orthopedic Surgery and Traumatology Department, University Children's Hospital, Belgrade, Serbia.

Borislav Cicović; https://orcid.org/0000-0002-2422-1604; borocicovic@yahoo.com; Faculty of Physical Education and Sport, University of East Sarajevo, Bosnia and Herzegovina.

Saša Bubanj; https://orcid.org/0000-0002-7849-6339; bubanjsasa@yahoo.co.uk; Faculty of Sport and Physical Education, University of Niš, Serbia.

Dejan Nikolić; https://orcid.org/0000-0002-0609-9916; denikol27@gmail.com; Faculty of Medicine, University of Belgrade, Serbia; Physical Medicine and Rehabilitation Department, University Children's Hospital, Belgrade, Serbia.

Iryna Skrypchenko; https://orcid.org/0000-0001-5895-3099; sit71@ukr.net; Department of Physical Education & Tactical and Special Training, Dnipropetrovsk State University of Internal Affairs, Ukraine.

Victor Rozhechenko; https://orcid.org/0000-0002-6034-2921; vrozecenko@gmail.com; Department of Physical Education & Tactical and Special Training, Dnipropetrovsk State University of Internal Affairs, Ukraine.

Milan Zelenović; (Corresponding author); https://orcid.org/0000-0003-0435-2399; milanzeleni13@gmail.com; Faculty of Physical Education and Sport, University of East Sarajevo, Bosnia and Herzegovina.

Cite this article as:
FAksović N, Bjelica B, Milanović F, Cicović B, Bubanj S, Nikolić D, Skrypchenko I, Rozhechenko V, Zelenović M. Evaluation and comparative analysis of the results of a vertical jump between young basketball and handball players. *Pedagogy of Physical Culture and Sports*, 2022;26(2):126–133.
https://doi.org/10.15561/26649837.2022.0207

Received: 12.02.2022
Accepted: 08.04.2022; Published: 30.04.2022

REVIEW ARTICLE

The compatibility of running-based anaerobic sprint test and Wingate anaerobic test: a systematic review and meta-analysis

Kuldeep Nara[ABCDE], Parveen Kumar[ABCD], Rohit Rathee[1BD], Jitender Kumar[ABC]

Department of Physical Education, Chaudhary Ranbir Singh University, Jind, Haryana, India

Authors' Contribution: A - Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim The objective of the study was to perform a systematic review of the literature and meta-analysis to determine the validity of running-based sprint test in relation to 30 second Wingate anaerobic test.

Material and Methods A search of the relevant literature was done using the key words, 'running-based anaerobic sprint test', 'RAST', 'Validity' 'repeated sprint' and 'Wingate'. Twelve studies including 368 participants were finalized to systematic review and meta-analysis. The mean ± standard deviation of the number of participants was 30.66 ± 16.17 years.

Results The summary of effects size were calculated to established the validity of running based sprint test (RAST) with 30 seconds Wingate test as a criterion measure. All studies indicate that effect size of Peak Power (PP) shows higher summary effects 0.58 (95%CI – 0.37, 0.79), similar outputs were observed for Mean Power (MP) 0.67 (95%CI – 0.45, 0.90). Therefore, the average outcomes were significantly different from zero.

Conclusions Running-based anaerobic sprint test is a valid alternative method of 30 seconds Wingate test to measure anaerobic power outputs of healthy individual belongs to various sports disciplines. Although, anaerobic capacity or power output is a determinant factor in power dominating sports. Therefore, RAST is compatible to laboratory-based Wingate 30 second anaerobic test (WAnT) in field-based settings.

Keywords: Sprint Test, Wingate Test, anaerobic test, validity

Introduction

The term "anaerobic" has been defined as "capable of living in the absence of air or free oxygen" (Webster 1977); when related to metabolism "anaerobic" refers to those metabolic processes which resynthesise adenosine triphosphate (ATP) and yield various end-products but do not involve the use of oxygen as a terminal substrate [1]. It is evident that the most instant source of energy production during muscular contraction is the anaerobic break-down of stored high-energy organic phosphate compounds (known as phosphagens) primarily adenosine triphosphate (ATP) and creatine-phosphate (CP). Repeated sprint ability can be synonymy used for the anaerobic capacity of an individual. The capability of sprint repeatedly with minimal recovery time is widely accepted as an important component of physical performance in various team sports such as basketball, handball, soccer, hockey etc. [2-4]. Maximal anaerobic power (Wmax) is an important parameter in many individual sports where explosive power is a dominant factor. Research evident that anaerobic power is significantly related with fat free mass muscle mass in body composition [5]. Anaerobic capacity/anaerobically attributable power is an important parameter for athletic performance, not only for short high-intensity activities but also for breakaway efforts and end spurts during endurance events [6]. In Skiers the contribution of anaerobic energy system was 26% and seemed independent of technique [7]. A linear regression analysis showed that there were high statistically significant correlation found between Anaerobic capacity and timing of 100m, 200m and 400m timing [8], so, the anaerobic capacity could be used as predictor of performance for these short distance speed dominant athletic events [9]. It was evident in literature that anaerobic power is a determinant factors of performance in different sports. While the assessment of anaerobic power is also an important factor as well as training to recognize the impact of intervention on anaerobic power [10, 11]. Assessment before and after an given intervention provide the effectiveness of a particular training. Accurate measurements of physical and physiological parameters provide an actual status of an athletes. The present status of an individual leads the further training needs.

The running-based anaerobic sprint test (RAST) has been developed to test anaerobic power using a repeated sprint protocol with variables that are analogous to the WAnT. The RAST involves six 35-meter sprints separated by 10 seconds of recovery. The distances and recovery time characteristic of the RAST protocol suggest that it might be an ideal test

doi:10.15561/26649837.2022.0208

to evaluate the RSA (repeated sprint ability) of field-based team sport athletes. Previous evaluations of the RAST have examined correlations of peak power (PP), mean power (MP), and fatigue index (FI) with the WAnT [12]. Various similar test has been designed with little variation in recovery time to measure anaerobic capacity of an individual [13, 14]. The Running Anaerobic Sprint Test (RAST) was developed in 1997 by Draper and Whyte to provide a means of determining anaerobic power, which was both inexpensive and simple to implement and thus accessible to coaches for players of all levels [15]. The power produced during each sprint was determined by the following formula: Power = (Body Mass × Distance2)/ Time3 . Peak power was defined as the power obtained during the fastest sprint and average power (for all six sprints) was calculated by taking the mean values of all sprints [16]. RAST is similar to the Wingate Anaerobic 30s cycle test (WANT) in that it provides coaches with measurements of power and fatigue index [17].

The 30 seconds Wingate anaerobic test (WAnT) is a valid test for assessment of anaerobic power output [18-27]. The WAnT is a laboratory-based test which require special equipment, such as computer-based cycle ergometer with mechanically braking system, desktops or big screens to display and much more device for articulation to each device. While, running based sprint test is a similar field-based test to measure anaerobic power output of an athlete. Therefore, the present study attempts to establish the validity and compatibility of running-based anaerobic sprint test in comparison to WAnT test.

Material and Methods

Literature Search Strategy

The systematic review of literature was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) norms and standards [28]. A systematic search of related literature was done for assessing the studies containing validity of running based anaerobic sprint test with WAnT test as criterion measure. The search includes manuscripts published between since 2000 to 2020, as well as thesis/dissertation completed and available between the selected time span. Google scholar, PubMed, Research gate, Academia, and Medline databases were searched using the terms 'running-based anaerobic sprint test', 'RAST', 'Validity' 'repeated sprint' and 'Wingate'. Reference lists from selected studies were also reviewed.

Inclusion and Exclusion Criteria

Subjects of any age were included. Studies meeting the following standards or inclusion criteria were taken into consideration for review in the present study: (1) Studies available in English and Hindi Language (2) participants assigned by random technique from different sports. (3) Studies reported subjects' characteristics, i.e., sample size, age, height, weight, gender, and game of the participants. (4) studies used Wingate test (WAnT) as criterion measure for assessing validity. (5) Studies reported correlation coefficient of the variables (relative to body mass) peak power (PP), and mean power (MP), between running-based anaerobic sprint test (RAST) and Wingate (WAnT) test. Studies were excluded for the following reasons: (1) studies not reported sample size (2) use different test than 30 second Wingate (WAnT) anaerobic test as criterion measure (3) animal subjects (4) patient's subjects (5) reported different sprint test.

Study Selection

A search of various e-databases with pre-defined key words including scan of reference list revealed 716 relevant studies between 2000 to 2020, a review of 20 years' studies taking into consideration. Based on title, or abstract or lack of relevant data structure 675 studies were excluded from the meta-analysis. Forty-one full text articles were evaluated, and 12 were included for the meta-analysis (see fig.1). Each study was deeply analyzed and coded for descriptive variables: body composition of Subjects (age, height, weight, gender and game of participants), sample size, running based anaerobic sprint test characteristics (no. of sprints, length of sprint, and recovery time). The studies conducted RAST and WAnT through proper guideline and protocols included in the present study for meta-analysis.

Data Collection

Anaerobic power data were extracted in the forms of dependent variables peak power (PP), and mean power (MP), reported in terms of mean of relative to body mass . Sample size and Correlation coefficient between running-based sprint test and Wingate test were also extracted for further computation of summary effect.

Study Characteristics

Twelve studies (see table 1) were collected through systematic literature review (SLR) contain 368 participants. The number of participants was 30.66±16.89 (mean±sd). Participant's age was 19.45±4.52 years. The average height of the participants was 173.84±10.58 centimetres, while body mass was 66.83±10.64 kilograms. The participants were enrolled in following sports i.e., soccer, basketball, hockey, cycling, football, sprint events, middle distance runners, volleyball with 3 to 5 years of playing experience reported in studies. Nine effects involved studies of men only; two studies [29, 30] included both men and women. Two studies contain little variation in administration & procedure of running-based anaerobic sprint test including 8 sprints of 40 meters [31] and 6 sprints of 15 meters [29] as well. Rest of studies include 6 sprints of 35 meters with 10 seconds recovery time between each sprint. All studies included in

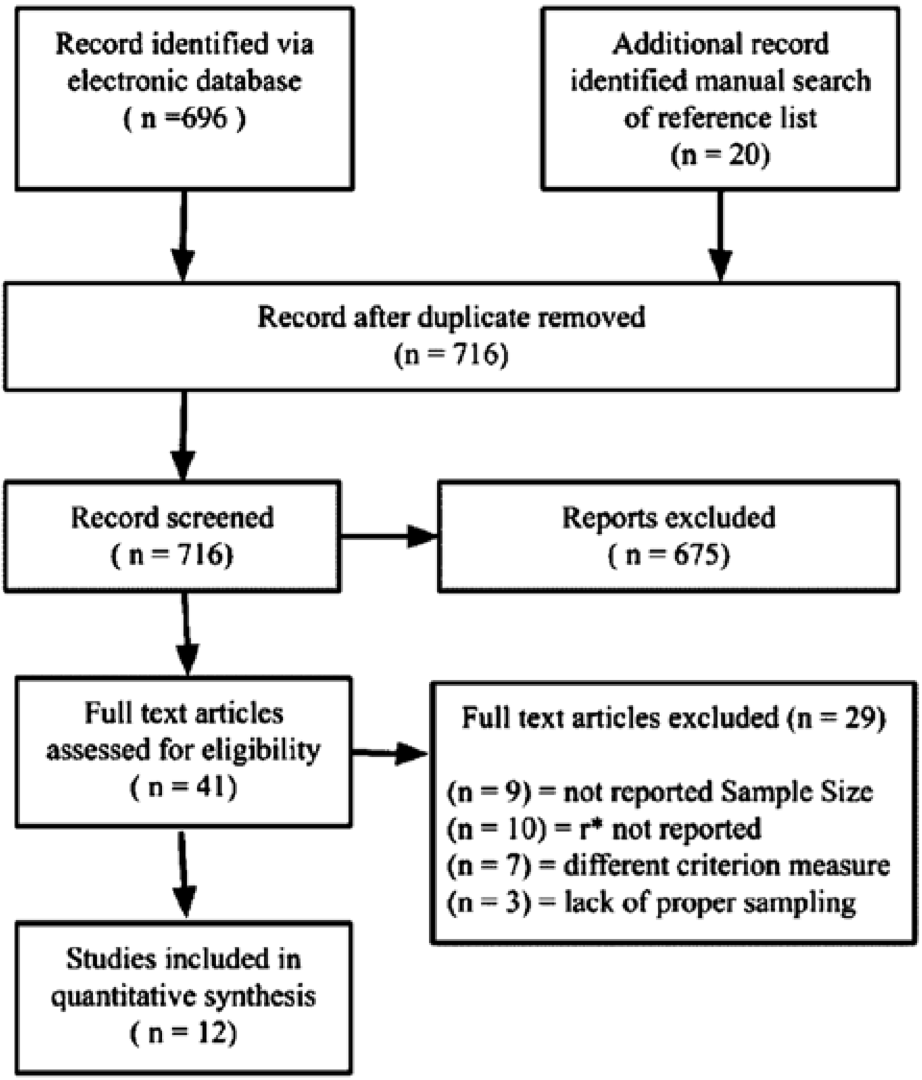


Fig. 1. Flow Chart of the Study Selection

meta-analysis were methodologically sound and met the assumptions of meta-analysis procedure. Mean values of outputs, i.e., Peak Power (PP), Mean Power (MP) and Fatigue Index were only reported by four studies [12, 30, 32, 33]. Eight studies were not reported mean values of pre-defined parameters. The studies included in meta-analysis were conducted on the following countries i.e., United Kingdom (1), India (2), Singapore (1), Canada (1), Turkey (1), South America (3), Poland (1), Germany (1) and Tunisia (1) respectively.

Meta-Analysis

summary effects were carried out using the correlation coefficient (see table 2) as the outcomes measure. A random effects model was fitted to the data [39]. Random effects model was applied because of variation in several factors (e.g., participants characteristics across studies, variation in number of participants among studies, nature of sports, length of recovery time in RAST, number of sprints). The amount of heterogeneity was estimated using the DerSemonian-Laired estimator [40]. In addition to the estimate of tau2, the Q-test for heterogeneity and I2 were used [41].

Data Synthesis and Analysis

Using Jamovi 2.2.5 with a module of MAJOR (meta-analysis for Jamovi 1.2.1- an interface for jamovi and the r package *'Metafor'*, an overall summary effects of correlation coefficient, associated 95% confidence interval were calculated [42]. Further, Meta-Essential workbook version 1.4 developed by Henk ven Rhee, Robert Suurmond and Tony Halk. The workbooks were licensed under the Creative Commons Attribution-Non-Commercial-ShareAlike 4.0 International License. The meta-essential workbook was specially used to estimate

Table 1. Characteristics of the Studies examining the validity of running-based anaerobic sprint test in context of Wingate (WAnT) test as a criterion measure

Study	Sample Size	Sex	Game	Age	Height	Weight	No. of Sprint
(Rashid Aziz & Chuan Teh, 2004)[31]	26	M	Hockey, Soccer	21.80	171.10	61.30	8×40
(Zagatto et al., 2009)[34]	11	M	Middle Distance Running	21.00	171.00	66.30	6×35
(Adamczyk, 2011)[30]	37	M/F	Sprint	18.70	182.70	72.30	6×35
Haj-Sassi et al., 2011)[35]	27	M	Athletics	20.60	176.00	68.20	NR*
(Zagatto et al., 2012)[36]	40	M	Volleyball, Soccer, Basketball, Athletic	19.78	176.00	70.34	6×35
(Queiroga et al., 2013)[32]	10	M	Cyclist	28.00	172.00	70.60	6×35
(Keir et al., 2013)[12]	8	M	Soccer	20.80	175.90	74.60	6×35
(Bongers et al., 2015)[29]	65	M/F	Basketball	10.00	143.00	36.00	6×15
(Reddy et al., 2015)[37]	45	M	Basketball	16.46	182.00	72.20	6×35
(Burgess et al., 2016)[16]	23	M	Soccer	24.00	180.00	75.40	6×35
(Hazir et al., 2018)[33]	31	M	Soccer	15.90	174.40	62.70	6×35
(Singh, 2019)[38]	45	M	Football	16.46	182.00	72.02	6×35

M = male participant, F = Female *participants*, NR = not reported

Table 2. Correlation of coefficient between running-based anaerobic sprint test (RAST) and Wingate test (WAnt)

Study	PP (r)	ES	(95% CI)	MP (r)	ES	(95% CI)
(Rashid Aziz & Chuan Teh, 2004)	0.63	0.74	(0.33, 1.15)	0.46	0.50	(0.09, 0.91)
(Zagatto et al., 2009)	0.46	0.50	(0.18, 0.82)	0.53	0.59	(0.27, 0.91)
(Adamczyk, 2011)	0.69	0.85	(0.51, 1.18)	0.55	0.62	(0.28, 0.95)
Haj-Sassi et al., 2011)	0.51	0.56	(0.16, 0.96)	0.77	1.02	(0.62, 1.42)
(Zagatto et al., 2012)	0.41	0.44	(-0.26, 1.13)	0.25	0.26	(-0.44, 0.95)
(Queiroga et al., 2013)	0.10	0.10	(-0.64, 0.84)	0.54	0.60	(-0.14, 1.34)
(Keir et al., 2013)	0.21	0.21	(-0.66, 1.09)	0.38	0.40	(-0.48, 1.28)
(Bongers et al., 2015)	0.86	1.29	(1.04, 1.54)	0.91	1.53	(1.28,1.78)
(Reddy et al., 2015)	0.31	0.32	(0.02, 0.62)	0.54	0.60	(0.30, 0.91)
(Burgess et al., 2016)	0.70	0.87	(0.43, 1.31)	0.60	0.69	(0.25, 1.13)
(Hazir et al., 2018)	0.25	0.26	(-0.11, 0.63)	0.22	0.22	(-0.15, 0.59)
(Singh, 2019)	0.31	0.32	(0.02, 0.62)	0.54	0.60	(0.30, 0.91)

PP = Peak Power Output, MP = Mean Power Output, ES = Effect Size, CI = Confidence Interval, r = correlation coefficient

the moderator analysis. The analysis was carried out using the correlation coefficient (see table 2) as the outcome measure. A random-effects model was fitted to the data. The amount of heterogeneity (i.e., tau^2), was estimated using the was estimated using the restricted maximum-likelihood estimator [43]. Distribution of true outcomes was determined to be heterogeneous is Q reached a significance level of $P<0.05$ and the sampling error accounted for less than 75% of the observed variance. An I2 statistics was also calculated to assess heterogeneity of effects. In case of any heterogeneity was detected (i.e., tau2 > 0, regardless of the results of the Q-test), prediction interval for the true outcomes was also provided. A fail-safe number was calculated to determine the number of unpublished studies of null findings necessary to negate the significant true outcomes or to address publication bias. Studentized residuals and Cook's distances are used to examine whether studies may be outliers and/or influential in the context of the model. Studies with a studentized residual larger than the $100 \times [1 - 0.05/ (2 \times n)]$th percentile of a standard normal distribution are considered potential outliers (i.e., using a Bonferroni correction with two-sided alpha = 0.05 for n studies included in the meta-analysis). Studies with a Cook's distance larger than the median plus six times the interquartile range of the Cook's distances are considered to be influential. The rank correlation test and the regression test, using the standard error of the observed outcomes as predictor, are used to check for funnel plot asymmetry [44].

Moderator Analysis

Three potential moderators were selected a priori based on their theoretical or empirical relation which leads to changes or variation in outputs of running-based anaerobic sprint test: age, standing height, and weight. Simple linear regression was used to compute the regression coefficient(β) of the slope, which is an estimate of the association between the moderator and a study's effect size.

Results

Peak Power Analysis

A total of k=12 studies were included in the analysis. The observed Fisher r-to-z transformed correlation coefficients ranged from 0.1003 to 1.2933, with the majority of estimates being positive (100%). The estimated average Fisher r-to-z transformed correlation coefficient based on the random-effects model was \hat{\mu} = 0.5826 (95% CI: 0.3710 to 0.7943). Therefore, the average outcome differed significantly from zero (z = 5.3948, p < 0.0001). According to the Q-test, the true outcomes appear to be heterogeneous (Q(11) = 46.0854, p < 0.0001, tau² = 0.0912, I² = 70.9600%). A 95% prediction interval for the true outcomes is given by -0.0458 to 1.2111. Hence, although the average outcome is estimated to be positive, in some studies the true outcome may in fact be negative. An examination of the studentized residuals revealed that one study [29] had a value larger than ± 2.8653 and may be a potential outlier in the context of this model. According to the Cook's distances, one study [29] could be considered to be overly influential. Neither the rank correlation nor the regression test indicated any funnel plot (see fig. 3a, fig. 3b) asymmetry (p = 0.9451 and p = 0.1657, respectively).

Mean Power Analysis

A total of k=12 studies were included in the analysis. The observed Fisher r-to-z transformed correlation coefficients ranged from 0.2237 to 1.5275, with the majority of estimates being positive (100%). The estimated average Fisher r-to-z transformed correlation coefficient based on the random-effects model was \hat{\mu} = 0.6736 (95% CI: 0.4491 to 0.8981). Therefore, the average outcome differed significantly from zero (z = 5.8812, p < 0.0001). According to the Q-test, the true outcomes appear to be heterogeneous (Q (11) = 54.5253, p < 0.0001, tau² = 0.1076, I² = 74.2488%). A 95% prediction interval for the true outcomes is given by -0.0073 to 1.3544. Hence, although the average outcome is estimated to be positive, in some studies the true outcome may in fact be negative. An examination of the studentized residuals revealed that one study [29] had a value larger than ± 2.8653 and may be a potential outlier in the context of this model. According to the Cook's distances, one study [29] could be considered to be overly influential. Neither the rank correlation nor the regression test indicated any funnel plot asymmetry (p = 0.7305 and p = 0.1747, respectively).

Moderator Analysis

Three potential moderators were recognized i.e., age, height and weight of the respondents. A moderator analysis was done in meta-essential software for the selected moderators. A simple linear weighted regression was run with the moderator as a predictor of the effects size of the study. In Meta-Essentials, it is not possible to run a multivariate regression analysis, so only one moderator was assessed at a time. The mean and standard deviation of age distribution of respondents was 19.45±4.52 years (95% CI: 16.89 – 22.01). The beta coefficient of age as a moderator was not statistically significant (β = -0.33, z = -1.04, P > 0.05), indicating no significant effects on effect size of study. The mean and standard deviation of height of respondents was 173.84±10.59 centimeters (95% CI: 167.85 – 179.83). The beta coefficient of height as a moderator was not statistically significant (β = -0.33, z = -0.97, P > 0.05), indicating no significant effects on effect size of study. The mean and standard deviation of weight of respondents was 66.83±10.64 kilogram (95% CI: 60.80 – 72.85). The beta coefficient of weight as a moderator was also not statistically significant (β = -0.38, z = -1.14, P > 0.05), indicating no significant effects on effect size of study. Effects were not significantly varied when moderating by age, height and weight of the respondents of the studies.

Discussion

The aggregated findings indicated that running based anaerobic sprint test (RAST) is valid (summary effects = 0.58 to 0.67) and effective means to measure anaerobic capacity in field settings. It is a valid alternative method of laboratory-based Wingate 30 second anaerobic test. The correlation coefficient of the studies in relation to peak power output were ranged from 0.10 to 0.86, and mean power output was 0.22 to 0.91 according to selected studies in meta-analysis. It is evident that anaerobic capacity play an important role in short-duration activities [45]. Its use is supported by; (a) the high correlations observed between maximal blood lactate and short-duration exercise performance presumably dependent upon anaerobic capacity, and (b) the

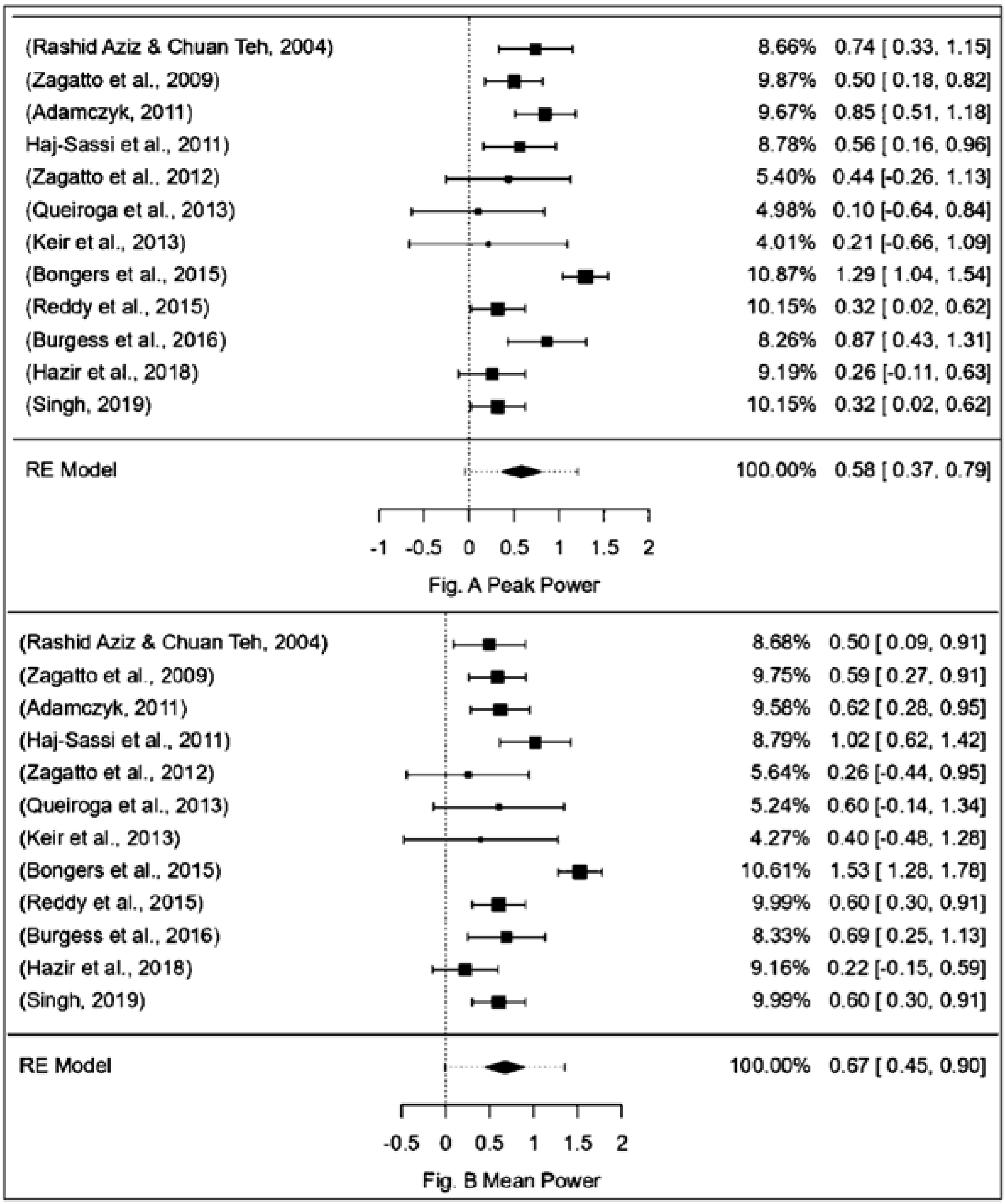


Figure 2. Forest plot of coefficient of correlation corresponding summery estimate (RE Model), modal fitting weights with 95% confidence interval and prediction interval (a) peak power PP (b) mean power, MP. The estimated correlation coefficient is based on random effects model.

higher maximal blood lactate values observed in sprint and power athletes (who would demonstrate higher anaerobic capacities) compared with endurance athletes or untrained people [46]. In some prospective studies, [47-50] a significant relationship (r = 0.88) was observed between anaerobic capacity and VO2max of cross-country runners and elite long distance runners. Anaerobic capacity is associated with developmental coordination disorder (DCD). The mean score of anaerobic measures (peak power & mean power) were significantly lower in children with DCD [51]. Anaerobic capacity is associated with body composition parameters also. A regression model developed by Durkalec-Michalski et.al. showed that BM (body mass) and FFM (fat free mass) significantly contributed to the prediction of VO2max and AP (anaerobic power) [52]. Anaerobic power is positively related to preponderance and size of muscle fibers types. Average power output is related to relative fiber size (average FT area/ average ST area); peak power, to % FT and to % FT area; and the power decrease to relative fiber size

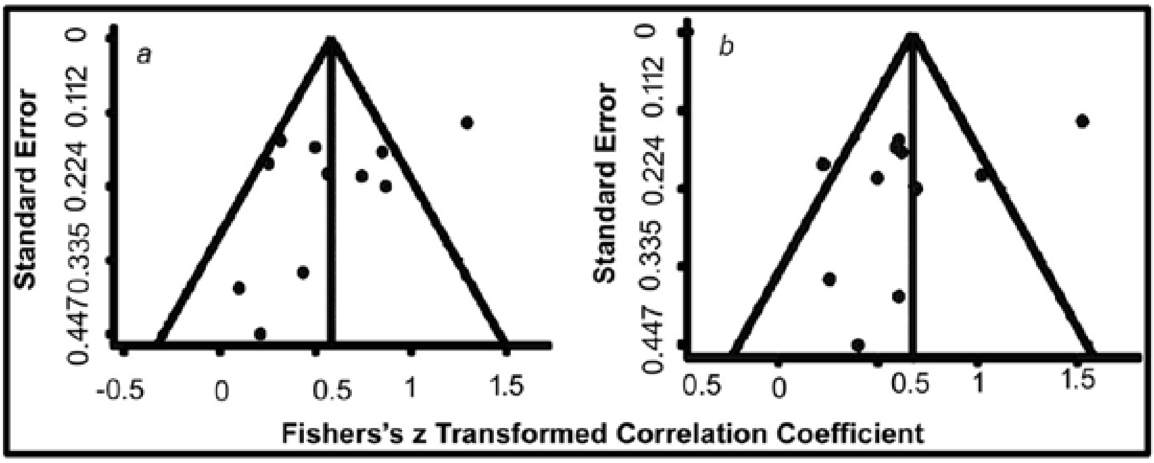


Figure 3. Funnel Plot of fisher's z transformed correlation coefficient versus study sample size (standard error) (a) Peak Power, (b) Mean Power.

[53]. Although, heritability is a determining factor for muscle fiber types associated with anaerobic capacity [54], the aerobic capacity could be increased through various trainings methods.

Although, there are several factors associated with maximal anaerobic power during the RAST test, for instance, motivation, surface, atmosphere, time of the test, recovery condition of athletes etc. Therefore, before the administration of the test examiner needs to consider the above factors into consideration to obtain reliable outcome.

Conclusions

This systematic review and meta-analysis revealed that running-based anaerobic sprint test (RAST) is a valid method to assess anaerobic capacity of an individual belongs to various age groups. Moderate to high degree of effects size (ES) or summary effects were observed in context of selected measures, i.e., peak power (PP) and mean power (MP). Relative to 30 second Wingate anaerobic test, RAST present an equally effective with a much lower cost of conduct and easy to administrate in field settings. Human performance laboratories are very expensive and not easy to operate for everyone. In this situation, coaches and trainers need an assessment tool which is equally effective as a laboratory test and easy to administrate.

References

1. Green S. A definition and systems view of anaerobic capacity. *European Applied Physiology and Occupational Physiology,* 1994;69:168–73. https://doi.org/10.1007/BF00609411
2. di Mascio M, Ade J, Bradley PS. The reliability, validity and sensitivity of a novel soccer-specific reactive repeated-sprint test (RRST). *European Journal of Applied Physiology*, 2015;115(12):2531–42. https://doi.org/10.1007/s00421-015-3247-0
3. Bishop D, Spencer M, Duffield R, Lawrence S. The Validity of a Repeated Sprint Ability Test. *Journal of Science and Medicine in Sport* 2001;4(1):19–29. https://doi.org/10.1016/S1440-2440(01)80004-9
4. Gharbi Z, Dardouri W, Haj-Sassi R, Chamari K, Souissi N. Aerobic and anaerobic determinants of repeated sprint ability in team sports athletes. *Biology of Sport*, 2015;32(3):207–12. https://doi.org/10.5604/20831862.1150302
5. Kim J, Cho H-C, Jung H-S, Yoon J-D. Influence of Performance Level on Anaerobic Power and Body Composition In Elite Male Judoists. *Journal of Strength and Conditioning Research,* 2011;25(5):1346–54. https://doi.org/10.1519/JSC.0b013e3181d6d97c
6. Noordhof DA, Skiba PF, de Koning JJ. Determining Anaerobic Capacity in Sporting Activities. *International Journal of Sports Physiology and Performance*, 2013;8(5):475–82. https://doi.org/10.1123/ijspp.8.5.475
7. Losnegard T, Myklebust H, Hallén J. Anaerobic capacity as a determinant of performance in sprint skiing. *Medicine and Science in Sports and Exercise*, 2012;44(4):673–81. https://doi.org/10.1249/MSS.0b013e3182388684
8. Katch VL, Weltman A. Interrelationship between anaerobic power output, anaerobic capacity and aerobic power. *Ergonomics*, 1979;22(3):325–32. https://doi.org/10.1080/00140137908924616
9. Smirniotoy A, Karatzanos E. Correlation of the running-based anaerobic sprint test (RAST) and performance on the 100M, 200M and 400M distance tests. *Journal of Human Movement studies*, 2005;49:77–92.
10. Spencer M, Fitzsimons M, Dawson B, Bishop D, Goodman C. Reliability of a repeated-sprint test for field-hockey. *Journal of Science and Medicine in Sport*, 2006;9(1):181–184. https://doi.org/10.1016/j.jsams.2005.05.001
11. Wragg CB, Maxwell NS, Doust JH. Evaluation of the reliability and validity of a soccer-specific

field test of repeated sprint ability. *European Journal of Applied Physiology*, 2000;83(1):77–83. https://doi.org/10.1007/s004210000246
12. Keir DA, Riault FT, Serresse O. Evaluation of the Running-Based Anaerobic Sprint Test as a Measure of Repeated Sprint Ability in Collegiate-Level Soccer Players. *Journal of Strength and Conditioning Research*, 2013;27(6):1671–8. https://doi.org/10.1519/JSC.0b013e31827367ba
13. Castagna C, Lorenzo F, Krustrup P, Fernandes-Da-Silva J, Póvoas SCA, Bernardini A, et al. Reliability characteristics and applicability of a repeated sprint ability test in young Male soccer players. *Journal of Strength and Conditioning Research*, 2018;32(6):1538–44. https://doi.org/10.1519/JSC.0000000000002031
14. Hendrik Madou K, Pribish C. Introduction, interpretation and reliability of a simple wingate based modified field running test to assess anaerobic capacity (of female soccer players in Germany and the United States of America). *MOJ Sports Med.* 2020;4(2):43–51.
15. Draper PN, Whyte G. Anaerobic performance testing. *Peak Perform*. 1997;3(5).:34-40.
16. Burgess K, Holt T, Munro S, Swinton P. Reliability and validity of the running anaerobic sprint test (RAST) in soccer players. *Journal of Trainology*, 2016; 5:24–9. https://doi.org/10.17338/trainology.5.2_24
17. Mackenzie B. *101 Performance Evaluation Tests*. London: Electric Word; 2005.
18. Legaz-Arrese A, Munguía-Izquierdo D, Carranza-García LE, Torres-Dávila CG. Validity of the Wingate anaerobic test for the evaluation of elite runners. *The Journal of Strength & Conditioning Research*, 2011;25(3):819–24. https://doi.org/10.1519/JSC.0b013e3181c1fa71
19. Bar-Or O. The Wingate anaerobic test an update on methodology, reliability and validity. *Sports Medicine*, 1987;4(6):381–94. https://doi.org/10.2165/00007256-198704060-00001
20. Dotan R. The Wingate anaerobic test's past and future and the compatibility of mechanically versus electro-magnetically braked cycle-ergometers. *European Journal of Applied Physiology*, 2006;98(1):113–6. https://doi.org/10.1007/s00421-006-0251-4
21. Dotan R, Bar-Or O. Load optimization for the Wingate anaerobic test. *European Journal of Applied Physiology and Occupational Physiology*. 1983;51(3):409–17. https://doi.org/10.1007/BF00429077
22. Barfield J-P, Sells PD, Rowe DA, Hannigan-Downs K. Practice effect of the Wingate anaerobic test. *Journal of Strength and Conditioning Research*, 2002;16(3):472–3. https://doi.org/10.1519/00124278-200208000-00022
23. Maud PJ, Shultz BB. Norms for the Wingate anaerobic test with comparison to another similar test. *Research Quarterly for Exercise and Sport*, 1989;60(2):144–51. https://doi.org/10.1080/02701367.1989.10607429
24. Beneke R, Pollmann CH, Bleif I, Leithäuser R, Hütler M. How anaerobic is the Wingate Anaerobic Test for humans? *European Journal of Applied Physiology*, 2002;87(4):388–92. https://doi.org/10.1007/s00421-002-0622-4
25. Coso J del, Mora-Rodríguez R. Validity of cycling peak power as measured by a short-sprint test versus the Wingate anaerobic test. *Applied Physiology, Nutrition, and Metabolism*. 2006;31(3):186–9. https://doi.org/10.1139/h05-026
26. Armstrong N, Welsman JR, Kirby BJ. Performance on the Wingate anaerobic test and maturation. *Pediatric Exercise Science*, 1997;9(3):253–61. https://doi.org/10.1123/pes.9.3.253
27. Coppin E, Heath EM, Bressel E, Wagner DR. Wingate anaerobic test reference values for male power athletes. *International Journal of Sports Physiology and Performance*, 2012;7(3):232–6. https://doi.org/10.1123/ijspp.7.3.232
28. Moher D, Liberati A, Tetzlaff J, Altman DG, Altman D, Antes G, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, 2009;6(7):1–6. https://doi.org/10.1371/journal.pmed.1000097
29. Bongers BC, Werkman MS, Blokland D, Eijsermans MJC, van der Torre P, Bartels B, et al. Validity of the pediatric running-based anaerobic sprint test to determine anaerobic performance in healthy children. *Pediatric Exercise Science*, 2015;27(2):268–76. https://doi.org/10.1123/pes.2014-0078
30. Adamczyk J. The Estimation of the RAST Test Usefulness in Monitoring the Anaerobic Capacity of Sprinters in Athletics. *PJST*. 2011;18(3):214–8. https://doi.org/10.2478/v10197-011-0017-3
31. Rashid Aziz A, Chuan Teh K. Correlation between tests of running repeated sprint ability and anaerobic capacity by Wingate cycling in multi-sprint sports athletes Stair-climbing in Singapore View project Ramadan View project. International *Journal of Applied Sports Sciences*, 2004;16(1):14–22.
32. Roberto Queiroga M, Gustavo Cavazzotto T, Yukari Katayama Bruno Sérgio Portela Marcus Peikriszwili Tartaruga Sandra Aires Ferreira K. Validity of the RAST for evaluating anaerobic power performance as compared to Wingate test in cycling athletes. *Motriz Journal of Physical Education*, 2013;19(4):696–702. https://doi.org/10.1590/S1980-65742013000400005
33. Hazir T, Kose MG, Kin-Isler A. The validity of Running Anaerobic Sprint Test to assess anaerobic power in young soccer players. *Isokinetics and Exercise Science*, 2018;26(3):201–9. https://doi.org/10.3233/IES-182117
34. Zagatto AM, Beck WR, Gobatto CA. Validity of the Running Anaerobic Sprint Test for Assessing Anaerobic Power and Perdicting Short-Distance Performance. *Journal of Strength and Conditioning Research*, 2009;23(6):1820–7. https://doi.org/10.1519/JSC.0b013e3181b3df32
35. Haj-Sassi R, Dardouri W, Gharbi Z, Chaouachi A, Mansour H, Rabhi A, et al. Reliability and Validity of a New Repeated Agility Test as a Measure of Anaerobic and Explosive Power. *Journal of Strength and COnditioning Research*, 2011;25(2):472–80. https://doi.org/10.1519/JSC.0b013e3182018186

36. Zagatto AM, Gomes EB, Loures JP. Can the Running-Based Anaerobic Sprint Test be used to Predict Anaerobic Capacity? deficiência View project Sensor Fusion for performance monitoring in sports View project. *Article in Journal of Exercise Physiology Online*, 2012;15(2):90–9.
37. Reddy Pv, DrKaukab Azeem I, Arabia YEmmanuel Kumar SS, DrQuadri Syed Javeed I, Babu D, JPrabhakar Rao I, et al. The validity of between Wingate test and Running-based Anaerobic Sprint Test (RAST) in young elite basketball players. *International Journal of Health, Education and Computer Science in Sports*, 2015;4(1):68–70.
38. Singh H. A comparative study of the validity of between Wingate test and running-based anaerobic sprint test (RAST) in young elite football players. *International Journal of Yogic, Human Movement and Sports Sciences*, 2019;4(1):1019–23.
39. Suurmond R, van Rhee H, Hak T. Introduction, comparison, and validation of Meta-Essentials: A free and simple tool for meta-analysis. *Research Synthesis Methods*, 2017;8(4):537–53. https://doi.org/10.1002/jrsm.1260
40. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Controlled Clinical Trials*, 1986;7(3):177–88. https://doi.org/10.1016/0197-2456(86)90046-2
41. Huedo-Medina T, Sanchez-Meca J, Marin-Martinez F, Botella J. Assessing heterogeneity in meta-analysis: Q statisticor I2 index? *Psychological Methods*, 2006;11(2):193. https://doi.org/10.1037/1082-989X.11.2.193
42. Viechtbauer W. Conducting Meta-Analyses in R with the metafor Package. *Journal of Statistical Software*, 2010;36(3):1–48. https://doi.org/10.18637/jss.v036.i03
43. Viechtbauer W. Bias and efficiency of meta-analytic variance estimators in the random-effects model. *Journal of Educational and Behavioral Statistics*, 2005;30(3):261–93. https://doi.org/10.3102/10769986030003261
44. Viechtbauer W, Cheung MW-L. Outlier and influence diagnostics for meta-analysis. *Research Synthesis Methods*, 2010;1(2):112–25. https://doi.org/10.1002/jrsm.11
45. Noordhof DA, Skiba PF, de Koning JJ. Determining anaerobic capacity in sporting activities. *International Journal of Sports Physiology and Performance*, 2013;8(5):475–82. https://doi.org/10.1123/ijspp.8.5.475
46. Green S, Dawson B. Measurement of Anaerobic Capacities in Humans Definitions, Limitations and Unsolved Problems. *Sports Medicine*, 1993;15(5):312–27. https://doi.org/10.2165/00007256-199315050-00003
47. Mayers N, Gutin B. Physiological characteristics of elite prepubertal cross-country runners. *Medicine and Science in Sports*, 1979;11(2):172–6.
48. Legaz-Arrese A, Munguía-Izquierdo D, Carranza-García LE, Torres-Dávila CG. Validity of the Wingate anaerobic test for the evaluation of elite runners. *The Journal of Strength & Conditioning Research*, 2011;25(3):819–24. https://doi.org/10.1519/JSC.0b013e3181c1fa71
49. Friedmann B, Frese F, Menold E, Bärtsch P. Effects of acute moderate hypoxia on anaerobic capacity in endurance-trained runners. *European Journal of Applied Physiology*, 2007;101(1):67–73. https://doi.org/10.1007/s00421-007-0473-0
50. Schnabel A, Kindermann W. Assessment of anaerobic capacity in runners. *European Journal of Applied Physiology and Occupational Physiology*, 1983;52(1):42–6. https://doi.org/10.1007/BF00429023
51. Aertssen WFM, Ferguson GD, Smits-Engelsman BCM. Performance on Functional Strength Measurement and Muscle Power Sprint Test confirm poor anaerobic capacity in children with Developmental Coordination Disorder. *Research in Developmental Disabilities*, 2016;59:115–26. https://doi.org/10.1016/j.ridd.2016.08.002
52. Durkalec-Michalski K, Nowaczyk PM, Podgórski T, Kusy K, Osiński W, Jeszka J. Relationship between body composition and the level of aerobic and anaerobic capacity in highly trained male rowers. *The Journal of Sports Medicine and Physical Fitness*, 2019;59(9):1526–35. https://doi.org/10.23736/S0022-4707.19.08951-5
53. Bar-Or O, Dotan R, Inbar O, Rothstein A, Karlsson J, Tesch P. Anaerobic capacity and muscle fiber type distribution in man. *International Journal of Sports Medicine*, 1980;1(02):82–5. https://doi.org/10.1055/s-2008-1034636
54. Calvo M, Rodas G, Vallejo M, Estruch A, Arcas A, Javierre C, et al. Heritability of explosive power and anaerobic capacity in humans. *European Journal of Applied Physiology*, 2002;86(3):218–25. https://doi.org/10.1007/s004210100522

Information about the authors:

Kuldeep Nara; https://orcid.org/0000-0002-2722-8350; kuldeepnara@crsu.ac.in; Department of Physical Education, Chaudhary Ranbir Singh University; Jind, Haryana, India.

Parveen Kumar; (Author for correspondence); http://orcid.org/0000-0002-3580-7854; parveenkumar@crsu.ac.in; Department of Physical Education, Chaudhary Ranbir Singh University; Jind, Haryana, India.

Rohit Rathee; http://orcid.org/0000-0002-3729-7384; rohit@crsu.ac.in; Department of Physical Education, Chaudhary Ranbir Singh University; Jind, Haryana, India.

Jitender Kumar; https://orcid.org/0000-0001-9898-4260; jitenderkumar@crsu.ac.in; Department of Physical Education, Chaudhary Ranbir Singh University; Jind, Haryana, India.

Cite this article as:
Nara K, Kumar P, Rathee R, Kumar J. The compatibility of running-based anaerobic sprint test and Wingate anaerobic test: a systematic review and meta-analysis. *Pedagogy of Physical Culture and Sports,* 2022;26(2):134–143.
https://doi.org/10.15561/26649837.2022.0208

Received: 11.02.2022

Accepted: 25.04.2022; **Published**: 30.04.2022

CONTACT INFORMATION
box 11135, Kharkiv-68, 61068, Ukraine
phone. 38-099-430-69-22
http://www.sportpedagogy.org.ua
e-mail: sportart@gmail.com

Information Sponsors, Partners, Sponsorship:

- Olympic Academy of Ukraine
- Ukrainian Academy of Sciences.

SCIENTIFIC EDITION (journal)
Pedagogy of physical culture and sports, 2022;26(2)
----
designer: Iermakov S.S.
editing: Yermakova T.
designer cover: Bogoslavets A.
administrator of sites: Iermakov S.S.
– –
passed for printing 30.04.2022
Format A4.
Red Banner str., 8, Kharkov, 61002, Ukraine.
PRINTHOUSE (B02 № 248 750, 13.09.2007).
61002, Kharkov, Girshman, 16a.