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Studia Kinanthropologica, vědecký časopis pro kinantropologii. Vydává Jihočeská univerzita v Českých Budějovicích, Pedagogická fakulta, katedra tělesné výchovy a sportu. **Od roku 2019 vychází třikrát ročně**. Příspěvky jsou přijímány průběžně. Katedra tělesné výchovy a sportu začala vydávat odborné periodikum již v roce 1996, které od roku 2000 nese název Studia Kinanthropologica a splňuje požadavky na recenzovaný časopis. **V roce 2010 Rada pro výzkum, vývoj a inovace zařadila Studia Kinanthropologica na Seznam recenzovaných neimpaktovaných periodik vydávaných v České republice**, které uvedla v oborech Národního referenčního rámce excelence (NRRE). Časopis je nadále uveden i v aktualizovaném Seznamu recenzovaných neimpaktovaných periodik vydávaných v ČR v roce 2014. Časopis Studia Kinanthropologica je indexován v databázi Medvik – Bibliographia medica Čechoslovaca (BMČ), Národní lékařské knihovny Praha. **Dne 29. dubna 2016 byl zařazen do databáze ERIH PLUS** (European Reference Index for the Humanities and the Social Sciences).

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Biomechanika	Behaviorální aspekty sportu
Zdravotní aspekty TVS	Dýchání ve sportu
Pedagogika TVS	Psychologie TVS

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Scientific Journal for Kinanthropology is mainly a place for publishing reports of empirical studies, review articles, or theoretical articles. Articles are published in Czech, Slovak, and/or English language. The author (senior author) is responsible for special and formal part of the article. All texts are subject to review process and assessed by at least two expert referees. The review procedure is authorless. Board of editors decide about article´s publishing having regard to scientific importance and review process. For content and linguistic correctness is responsible author, authors of individual contributions.

Aims and Scope:

Sports training	Humanities in Sport
Applied physical activities	Physiotherapy
Biomechanics	Behavioural aspects of sport
Health aspects of physical education and sport	Breathing in Sport
Sport pedagogy	Sport psychology

Obsah

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TESTOVÁNÍ VÝSKOKU JEDNONOŽ A OBOUNOŽ U VÝKONNOSTNÍCH SPORTOVNÍCH GYMNASTŮ

SINGLE-LEG AND BOTH LEG JUMP TESTING FOR PERFORMANCE SPORTS GYMNASTS

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Abstract

This article deals with the comparison of jumps of the left and right lower limbs, the muscles of both lower limbs and subsequently their correlation, both in terms of jump and in terms of the amount of muscle mass. Subsequently, the laterality of the lower limbs is also assessed. The average age of probands is 8.58 years ± 1.88 years, the average height is 132.3 cm ± 11.4 cm with an average weight of 28.17 kg ± 11.93 kg. They are tested on a one-time test on the Tanita tread weight, which analyzes their percentage of fat, body water and diagnoses their segmental distribution of muscle mass. Furthermore, the probands are tested in the form of jumping measurements on the LEM 10 with ProJump jumping platform, where two jumps from the right and left lower limbs are performed for each of them, followed by one leg jump. A significant relationship between the amount of muscle mass and the jump of the probands was not demonstrated on either of the limbs measured. A total of 56% of gymnasts were found to be related between the preferred lower limb and its better reflective performance.

Keywords: body composition; laterality; measurement; talent; muscle mass

Souhrn

Tento článek se zabývá porovnáním výskoku pravé a levé dolní končetiny a následnou komparací s množstvím svalové hmoty na obou končetinách u mladých výkonnostních gymnastů. Následně se také posuzuje lateralita dolních končetin. Zajímala nás ale odrazová končetina. Testovaný vzorek byl složen z 9 výkonnostních gymnastů mladšího školního věku z oddílu TJ Merkur České Budějovice. Průměrný věk probandů je 8,58 let ± 1,88 roku, průměrná výška je 132,3 cm ± 11,4 cm s průměrnou hmotností 28,17 kg ± 11,93 kg, kteří byli jednorázově testováni na nášlapné váze Tanita, která analyzuje jejich procento tuku, tělesné vody a diagnostikuje jejich segmentální rozložení svalové hmoty. Dále byli gymnasté testováni formou měření výskoku na odrazové plošině LEM 10 with ProJump, kde byly u každého z nich provedeny dva skoky z pravé a levé dolní končetiny a následně jeden skok snožný. Významný vztah mezi množstvím svalové hmoty a výskoky probandů prokázán nebyl, a to ani na jedné z měřených končetin. Celkem u 56 % gymnastů byla zjištěna souvislost mezi preferovanou (odrazovou) dolní končetinou, a i jejím lepším odrazovým výkonem.

Klíčová slova: lateralita; měření; složení těla; svalová hmota; talent

Introduction

Gymnastics became an officially recognized sport in 1896 when it was included in the program of the first modern Olympic Games, and it has since remained a celebrated highlight of the Games (Havlíčková et al., 2006). Skolnik and Chernus (2011) note that gymnastics, along with other sports in similar categories, encompasses a wide range of competitive and training programs. For children and adolescents, it is possible to examine the specific components of sports training and their unique characteristics. Conditioning training includes strength training, as well as speed, endurance, flexibility,

and coordination exercises. For young athletes, it is beneficial to prioritize skill acquisition approaches that simplify these skills (for example, through play), apply them comprehensively, and offer a variety of suitable activities (Piňos, 2007). Additionally, training should be adapted to the athletes' age (Bahenský & Bunc, 2018; Bahenský et al., 2021). In this context, the research focused on comparing the jump performance of the right and left lower limbs and the subsequent comparison with the muscle mass of both limbs in young competitive gymnasts from the Merkur České Budějovice clubs. At this level, gymnasts compete in national championships and cup competitions and engage in daily 3-hour training sessions. This rigorous training places higher demands on agility, joint mobility, strength, and, importantly, the development of jump capabilities (explosive strength) in the lower limbs. Accordingly, the study also examined lower limb laterality (preferred jumping leg) in these gymnasts and compared it with their jump performance. Laterality can be morphological or functional. Morphological laterality evaluates asymmetries in body parts and organs (Mohr et al., 2003). Functional laterality, understood as the asymmetry of motor (hand, foot) or sensory (eye, ear) paired organs, is characterized by the preferential use of one paired organ (Hatta et al., 2005). Correct terminology defines the dominant limb in terms of laterality as the more skillful one, which is typically the non-jumping leg. The aim of this pilot project is to compare the jump performance of the right and left lower limbs and subsequently assess the muscle mass in both limbs in young competitive gymnasts. Additionally, the project aims to determine the laterality of the lower limbs and its relationship with jump performance.

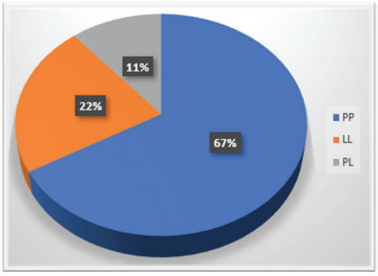
Methods

Sample Characteristics: The tested sample consisted of 9 young competitive gymnasts from the TJ Merkur České Budějovice club in the early school-age category. The average age of the participants was 8.58 years ± 1.88 years, with an average height of 132.3 cm ± 11.4 cm and an average weight of 28.17 kg ± 11.93 kg. Data were obtained using a Tanita BC 418 MA segmental analyzer and an LEM 10 force plate with ProJump. This sample was purposefully selected based on performance level (10–15 hours of training per week, participation in cup and championship competitions, including the Czech Republic Championship – higher performance class for juniors). All participants were in good physical condition at the time of testing, with no injuries or rehabilitation processes ongoing. Consent was obtained from the parents of all participants, and test results were made available to them upon request. All procedures were conducted in accordance with ethical standards.

Research Design: In this study, we cannot classify it as a true experiment in the strict sense of the term. The selection of the research sample was not random; rather, it was predetermined and intentionally selected by us. Ježek et al. (2006) and Shadish et al. (2002) note that such sampling is typical for a quasi-experiment. This selection partially threatens internal validity; however, Thomas and Nelson (1996) state that, despite this, we still retain control over the independent variable. Due to the young age of the gymnasts, it was not possible to conduct the Wingate test, so the study focused solely on assessing jump ergometry, body composition, and laterality. Testing was conducted in the exercise diagnostics laboratory at the Department of Physical Education at JCU. Participants were tested in the afternoon, generally at the same time between 3 and 5 PM, prior to training, and at least three hours after a major meal. Both the participants and their parents were informed about the entire testing procedure, and participants' current health status and parental consent were confirmed through questionnaires. All tests were performed in a standardized manner. Body composition measurements, specifically examining body fat percentage and the distribution of muscle mass between the right and left limbs, were conducted using the Tanita BC 418 MA scale. The Jumpmax test on the LEM 10 force platform with ProJump was used to measure maximum jumps from the right and left limbs, as well as a two-legged jump; the test was repeated twice, with hands on the hips, and the higher result was used for statistical analysis. This testing was supervised by competent laboratory personnel. Another objective was to determine the laterality of the lower limbs. The test was conducted at Gymcentrum Merkur České Budějovice, where the take-off leg was assessed by having participants kick a ball over a short distance, perform a single-leg jump to a bar, and execute a lunge from either leg. Pearson's correlation coefficient, a parametric test, was used for statistical analysis.

Results

Obrázek 1./ Figure 1.
Shoda odrazové dolní končetiny a odrazového výkonu./ Conformity of rebound lower limb and rebound performance.

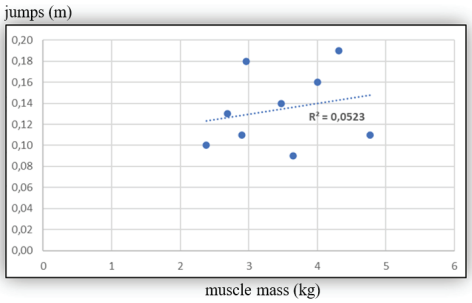


	rebound lower limb	best rebound performence	equally
Participant 1	left	right	no
Participant 2	right	right	yes
Participant 3	right	right	yes
Participant 4	right	right/left	equally
Participant 5	right	right/left	equally
Participant 6	left	left	yes
Participant 7	right	right	yes
Participant 8	right	right	yes
Participant 9	left	right	no

In this study, we aimed to determine whether the preferred take-off limb of competitive gymnasts would correspond to the strength performance of the right or left limb (rebound performance). It was found that approximately half of the gymnasts showed a correlation between the preferred take-off limb and superior rebound performance, while the other half did not. Thus, the result is inconclusive, and the hypothesis cannot be confirmed.

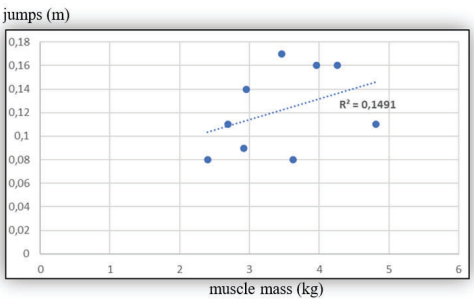
Obrázek 2./ Figure 2.
Porovnání výsledků Jumpmax testu s množstvím svalové hmoty na pravé dolní končetině./ Comparison of Jumpmax test results with muscle mass on the right lower limb.

	muscle mass (kg) (right lower limb)	better of two jumps (m)
Participant 1	2,96	0,18
Participant 2	2,38	0,10
Participant 3	4,31	0,19
Participant 4	4,00	0,16
Participant 5	4,77	0,11
Participant 6	3,47	0,14
Participant 7	2,90	0,11
Participant 8	2,69	0,13
Participant 9	3,65	0,09



Obrázek 3./ Figure 3.
Porovnání výsledků Jumpmax testu s množstvím svalové hmoty na levé dolní končetině./ Comparison of Jumpmax test results with muscle mass on the left lower limb.

	muscle mass (kg) (left lower limb)	better of two jumps (m)
Participant 1	2,95	0,14
Participant 2	2,4	0,08
Participant 3	4,26	0,16
Participant 4	3,96	0,16
Participant 5	4,81	0,11
Participant 6	3,46	0,17
Participant 7	2,92	0,09
Participant 8	2,69	0,11
Participant 9	3,63	0,08



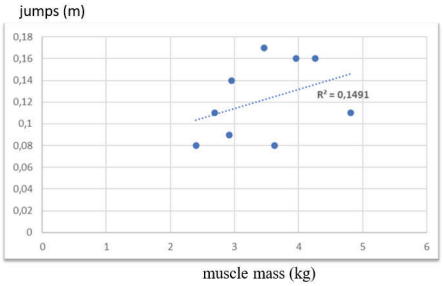
In Figure 2, we can observe a comparison of gymnasts' values for the better of two tested jumps in the Jumpmax test for the right limb and the muscle mass of that limb. The blue dots in the graph represent the individual participants and their respective results. The X-axis shows the muscle mass of the right lower limb in kilograms, while the Y-axis represents the height of the better jump for the right lower limb in meters. According to the Pearson correlation coefficient calculation for the right

lower limb, based on muscle mass and jump height in the Jumpmax test, a value of r = 0.229 was obtained, indicating a weak linear relationship.

In Figure 3, we can observe a comparison of gymnasts' values for the better of two tested jumps in the Jumpmax test for the left limb and the muscle mass of that limb. The blue dots in the graph represent the individual participants and their respective results. The X-axis shows the muscle mass of the left lower limb in kilograms, while the Y-axis represents the height of the better jump for the left lower limb in meters. According to the Pearson correlation coefficient calculation for the left lower limb, based on muscle mass and jump height in the Jumpmax test, a value of r = 0.386 was obtained, indicating a moderate linear relationship.

Obrázek 4./ Figure 4.
Porovnání výsledků Jumpmax testu s množstvím svalové hmoty pro obě dolní končetiny./ Comparison of Jumpmax test results with muscle mass for both lower limbs.

	muscle mass (kg) (bouth lower limbs)	better of two jumps (m)
Participant 1	5,91	0,25
Participant 2	4,78	0,19
Participant 3	8,57	0,32
Participant 4	7,96	0,31
Participant 5	9,58	0,25
Participant 6	6,93	0,3
Participant 7	5,82	0,28
Participant 8	5,38	0,22
Participant 9	7,28	0,2



In Figure 4, we see a comparison of gymnasts' results in the bilateral jump (Jumpmax test) and the total muscle mass of their lower limbs. The blue points in the graph represent the individual participants and their respective outcomes. The X-axis shows the total muscle mass in the lower limbs in kilograms, while the Y-axis represents the height of the bilateral jump in meters. We can observe that three gymnasts, who had above-average muscle mass in their lower limbs, also achieved above-average jump heights. For participant #7, the jump height was higher despite having lower muscle mass, whereas for participant #9, the reverse was true. The remaining participants exhibited both lower muscle mass and jump heights. The average difference between unilateral and bilateral jump heights for these high-performance gymnasts was approximately double. While the mean jump height for the right lower limb was 0.13 m and for the left was 0.12 m, the mean bilateral jump height reached 0.26 m. According to the Pearson correlation coefficient calculation for both lower limbs, considering muscle mass and jump height in the Jumpmax test, a value of r = 0.497 was obtained, indicating a moderate linear correlation.

Obrázek 5./ Figure 5.
Porovnání výsledků svalové hmoty a odrazového výskoku dolních končetin po vzájemném odečtení./ Comparison of results of muscle mass and rebound jump of lower limbs after mutual deduction.

	muscle mass (kg) R-L	jump (m) R-L
Participant 1	0,01	0,04
Participant 2	-0,02	0,02
Participant 3	0,05	0,03
Participant 4	0,04	0
Participant 5	-0,04	0
Participant 6	0,01	-0,03
Participant 7	-0,02	0,02
Participant 8	0	0,02
Participant 9	0,02	0,01

After subtracting the values and calculating the Pearson correlation coefficient of r = 0.081, we can conclude that the difference in muscle mass between the right and left limbs does not correlate with the difference in jump height when rebounding from either lower limb.

Discussion

Our tested sample consists of only 9 gymnasts. For the lower limbs, 6 participants preferred jumping with their right limb, and 3 with their left. However, some children in this sample may still have undecided laterality, as confirmed by Drnková and Syllabová (1991) in their book, which states that according to some researchers studying the time factor in the development of brain hemisphere specialization, the patterns of cerebral asymmetry, speech localization, and limb laterality may not stabilize before the age of 10 or 11. Therefore, we cannot say with certainty whether this laterality is already established and valid. Laterality is primarily innate, so, conversely, laterality in this age group does not correlate with the amount of muscle mass in the lower limbs in terms of lateral asymmetry, nor with the gymnasts' performance in explosive strength of the lower limbs. Youth gymnastics training does not appear to affect laterality. This finding is consistent with similar results from Krajcigr et al. (2023) in adolescent football players.

A significant relationship between the amount of muscle mass and the jumps of the participants was not demonstrated, neither for either of the measured limbs. For the right lower limb, the correlation reached r = 0.229, indicating a weak dependency between muscle mass and jump height. For the left limb, the correlation was slightly higher at r = 0.386, reflecting a moderate dependence, but still relatively low. Similar to the study by Bahenský et al. (2021), there is no general relationship between rebound strength and the amount of muscle mass in the lower limbs. For the two-legged jump, when comparing total muscle mass, the linear relationship was the highest, with r = 0.497. However, this represented only a moderate relationship, and considering the small sample size, this result is negligible. The study therefore found no relationship between lower limb strength and muscle mass, which aligns with published results (Flanagan et al., 2007).

Regarding the distribution of muscle mass across the lower limbs of our tested competitive gymnasts, we can say that there are minimal muscle differences, with the largest difference being only 0.05 kg, which indicates a low risk of developing muscle imbalance. This statement is confirmed by Havláková (2015), who addressed the issue of unilateral sports load on muscle imbalances in younger school-aged children. She concluded that, unlike recreational or non-athletic children, competitive athletes experience these problems the least.

A balanced training regimen, which evenly stresses both dominant and non-dominant limbs, can contribute to reducing potential differences in limb involvement during physical performance and aid in the development of the required physical skills (Faigenbaum et al., 2009). Some studies suggest that the more general the movement, or the more adapted an individual is to a specific physical activity, the closer the relationship between the amount of muscle mass in the affected muscle groups and the speed-strength performance. This means that muscle mass plays a significantly larger role in speed-strength performance in movements to which an individual has adapted, compared to specific physical activities that are trained in a much shorter period than basic movement activities (Macdougall, 2003). A limitation of our work that could affect the generalizability of the results is the small sample size.

Conclusion

In conclusion, no significant dependence was found between the amount of muscle mass and jump height in the lower limbs of the participants. The hypothesis that muscle mass in competitive gymnasts would significantly correlate with rebound performance was not confirmed. Similarly, to the study by Bahenský et al. (2021), there is no general relationship between rebound strength and muscle mass in the lower limbs. Regarding the other research objectives, we were interested in whether the preferred rebound limb would correlate with the strength performance of the right/left limb in competitive gymnasts. It can be stated that only half of the gymnasts showed a connection between the preferred rebound limb and its better rebound performance. Therefore, no significant correlation was found. In terms of muscle mass distribution across the lower limbs of our tested competitive gymnasts, we can say that the muscle differences are minimal, with the largest difference being only 0.05 kg, indicating a low risk of developing muscle imbalance.

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VYUČOVANIE ZIMNÝCH ŠPORTOV NA ZÁKLADNÝCH ŠKOLÁCH CEZ INOVATÍVNE UČEBNÉ MATERIÁLY

TEACHING WINTER SPORTS IN PRIMARY SCHOOLS THROUGH INNOVATIVE TEACHING MATERIALS

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Abstract

The aim of the study is to provide information on how primary school teachers perceive the quality, conditions and possibilities of professional education in the field of winter sports teaching. We focused our findings on a sample of 229 respondents in order to obtain an answer to the questions, in particular, whether the opinions of men and women differ regarding the need for professional education for teaching winter sports and what is their demand for a possible innovation of teaching materials for teaching winter sports. Through statistical analysis (Chi-square), we found that there is a significant difference in the approach to this field between male and female teachers, especially from the point of view of interest in further education, in the way of obtaining new information and knowledge, and also in the demand for the format of study material. From the point of view of teachers' requests for a possible innovation of teaching materials for teaching winter sports, we found that there was a significant group of respondents (22.94 %) who have a negative attitude towards this area (the answer is "I don't need"). Of course, the remaining part of the teachers want innovation to take place in this area as well and they present the demand that the teaching formats in particular be adapted to the current modern information and communication age, and they request that the transfer of information from the content of the curriculum be transformed into a mobile environment.

Keywords: winter sports teachers; requirements for format and content of teaching materials

Souhrn

Cieľom štúdie je poskytnúť informácie o tom, ako vnímajú učitelia a učiteľky základných škôl kvalitu, podmienky a možnosti odborného vzdelávania sa v oblasti výučby zimných športov. Svoje zistenia na vzorke 229 respondentov sme smerovali k tomu, aby sme získali odpoveď najmä na otázky, či sa odlišujú názory mužov a žien k potrebe odbornej vzdelanosti pre vyučovanie zimných športov a aká je ich požiadavka na možnú inováciu učebných materiálov pre vyučovanie zimných športov. Cez štatistickú analýzu (Chí-kvadrát) sme zistili, že sa objavuje významná odlišnosť v prístupe k tejto oblasti medzi učiteľmi a učiteľkami najmä z pohľadu záujmu o ďalšie vzdelávanie, v spôsobe získavania nových informácii a poznatkov a taktiež pri požiadavke na formát študijného materiálu. Z pohľadu požiadavky učiteľov a učiteliek na možnú inováciu učebných materiálov pre vyučovanie zimných športov sme zistili, že sa tu objavila výrazná skupina respondentov (22,94 %), ktorá sa k tejto oblasti stavia negatívne (odpoveď „nepotrebujem“). Samozrejme zvyšná časť učiteľov a učiteliek chcú aby aj v tejto oblasti došlo k inovácii a prezentujú požiadavku aby sa najmä učebné formáty prispôsobili súčasnej modernej informačno-komunikačnej dobe a žiadajú aby sa prenos informácii z obsahu učiva transformoval aj do mobilného prostredia.

Klíčová slova: učitelia a učiteľky zimných športov; požiadavky na formát a obsah učebných materiálov

Introduction

The teaching of skills and the development of knowledge in the field of winter sports have long been embedded in the educational process at primary schools in Slovakia. In general, it primarily focuses on traditional winter sports and physical activities such as downhill (alpine) and cross-country skiing, snowboarding, and ice skating. All these activities are, of course, conditioned by the resources and conditions of each individual school. The teaching itself is aimed not only at acquiring new skills and abilities but also at strengthening health, due to the specific conditions of teaching in the winter environment. The importance of this type of education is also evident in the context of creating lifelong movement habits for the younger generation. The teacher's (instructor's) expertise and skill quality play a primary role in this (Pighetti, Mateer, Allison, 2022). Investigations and research that dealt with the field of training of experts (teachers, instructors, coaches) of winter sports are wide-ranging and present several interesting trends. There are topics dealing with personality and attitudes, whether of participants or teachers, where e.g. Bridgwater (1982) focused on teaching effectiveness in relation to personality type. Plastoi (2017) points out that teaching winter sports imposes high demands on educators not only in terms of their social characteristics but also in terms of their ability to accept the specifics of a student's personality. Cigrovski, Radman et al. (2014) studied the attitudes of participants (beginners) toward skiing and found that a suitable teaching structure (methodology) positively influences their attitude toward skiing sports. A significant factor influencing a student's attitude toward skiing is primarily their fear of injury (Nagel, Reuleaux, 1985). According to Khong Chiu, Kayat (2010), positive motivation from the teacher can significantly influence students' interest in physical activities. Several studies indicate that there are differences between men and women in their approach to sports activities, often to the detriment of women (Kumar Tyagi, Kumar, 2013; Lindstrom, Hanson, Ostergren, 2001; Cigrovski et al., 2014, etc.). Understanding these variables, which positively or negatively influence students' attitudes toward acquiring new skills, is an essential need for improving the teaching of various winter sports.

Through our study, we aim to summarize current information on the level of professional preparedness of teachers – instructors of winter sports at primary schools, with the goal of identifying their requirements for possible innovation of teaching materials. This study addresses two main questions:

- Do the opinions of men and women differ regarding the need for professional education in winter sports teaching?

- What are their demands for possible innovation of teaching materials for winter sports instruction?

Methodology

Sample

As part of our grant project KEGA 032UMB-4/2022 *Innovative Teaching Materials for Physical Education Teachers in Primary Schools with a Focus on Winter Seasonal Physical Activities*, we contacted the management of 89 public primary schools in the Banská Bystrica region via official email addresses at the beginning of February 2023, informing them that we were sending an online questionnaire focused on the teaching of winter sports in the second grade of primary schools. The questionnaire was made available from March 15, 2023, to April 14, 2023. We requested that this information be passed on to all teachers involved in the teaching of winter sports at their school. During this period, we received relevant feedback from 229 respondents (Table 1), which represents 13.74 % of the total number of 1,667 second-stage teachers in public primary schools in the Banská Bystrica region (Statistical Yearbook - Primary Schools - CVTI SR).

Tabuľka 1./ Table 1.
Charakteristiky skúmaného súboru./ Characteristics of the studied sample.

Gender	Respondents' Age					Total
	Under 30 years	31 – 40 years	41 – 50 years	51 – 60 years	Over 60 years	
Male	23	30	25	22	9	109
Female	22	30	35	30	3	120
Total	45	60	60	52	12	229

Methods

In January 2023, we created an online questionnaire as part of the grant project KEGA 032UMB-4/2022. We conducted a so-called *non-exhaustive survey* (a sample of the target population). After 30 days of its availability, we closed the access to the online questionnaire and exported the collected data into an XLS format for subsequent evaluation using statistical software. In total, we received 277 questionnaire, of which 48 erroneous or incomplete responses were excluded from the final evaluation. The questionnaire was anonymous. We processed the data using basic statistical methods and analysed it through percentage and comparative analysis.

Statistical Analysis

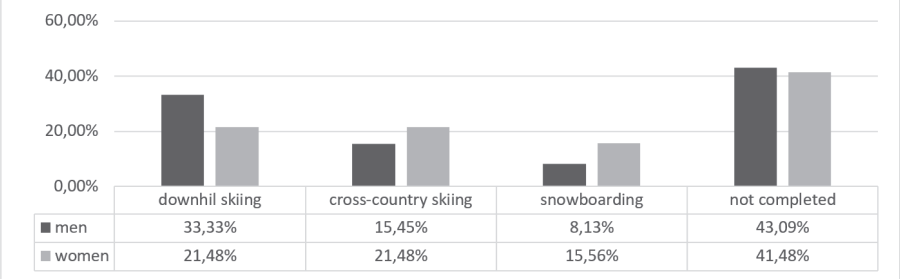
For the statistical evaluation of the collected data, we used the non-parametric Chi-square test, which we applied to assess the statistical significance of differences in the selected intersexual criterion (men vs. women). Statistical significance was evaluated at the 1 % and 5 % probability levels.

Results

The basic descriptive parameters and results of the comparison of opinions of the surveyed respondents (teachers) implementing winter sports in the teaching of physical education for second-stage primary school students are presented in Figures 1-5. From the perspective of statistical significance, we found that in the area of professional preparation (Figure 1) and in the area of the most frequently used formats of teaching materials (Figure 4), there are no significant differences between men and women. Significant differences ($p<0.01$) were recorded in the area of interest in further education (Figure 2), in the way of acquiring new information (Figure 3), and in the demand for a specific (innovative) format of teaching materials (Figure 5).

Obrázok 1./ Figure 1.

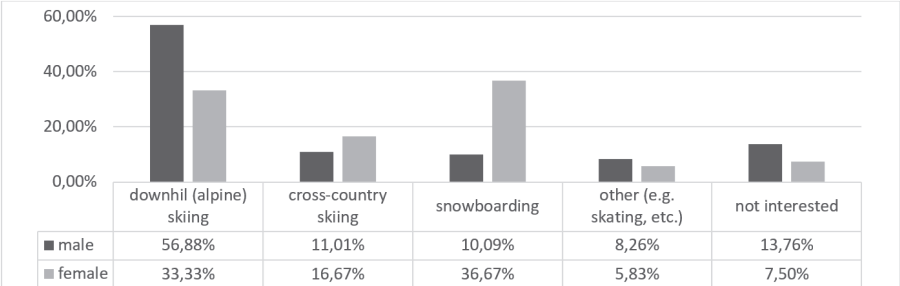
Absolvovanie kurzu zameraného na vyučovanie zimných športov po ukončení vysokoškolského štúdia; chi - štatisticky nevýznamné ($\chi^2_{(3)} = 7{,}584$; $p=0{,}055$)./ Completion of a course focused on teaching winter sports after completing university studies; Chi-square - statistically insignificant (χ^2 (3) = 7.584; $p = 0.055$).



	downhil skiing	cross-country skiing	snowboarding	not completed
men	33,33%	15,45%	8,13%	43,09%
women	21,48%	21,48%	15,56%	41,48%

Obrázok 2./ Figure 2.

Záujem učiteľov o ďalšie vzdelávanie z oblasti vyučovania zimných športov; chi - štatisticky významné $p<0{,}01$ ($\chi^2_{(4)} = 27{,}830$; $p=1{,}349$ E-05)./ Interest of teachers in further education in the field of teaching winter sports; Chi-square - statistically significant $p < 0.01$ (χ^2 (4) = 27.830; $p = 1.349$ E-05).

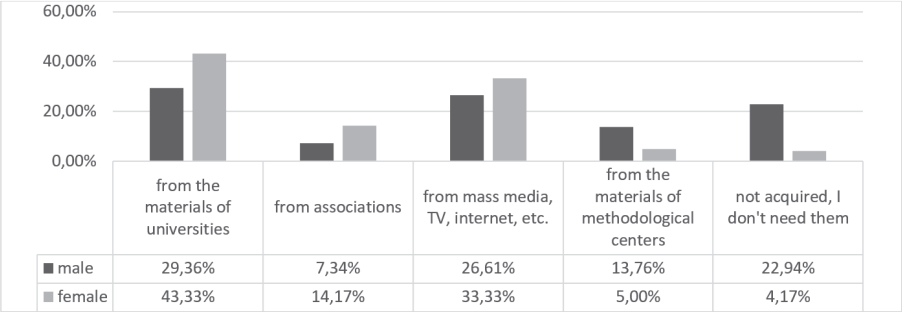


	downhil (alpine) skiing	cross-country skiing	snowboarding	other (e.g. skating, etc.)	not interested
male	56,88%	11,01%	10,09%	8,26%	13,76%
female	33,33%	16,67%	36,67%	5,83%	7,50%

From the perspective of respondents' interest in further education (Figure 1) in the winter sports types we investigated (alpine skiing, cross-country skiing, and snowboarding), we found that alpine skiing were preferred the most (27.41 %). As many as 42.29 % of respondents have not participated in any activity to further develop their knowledge in the field of winter sports since completing their university studies.

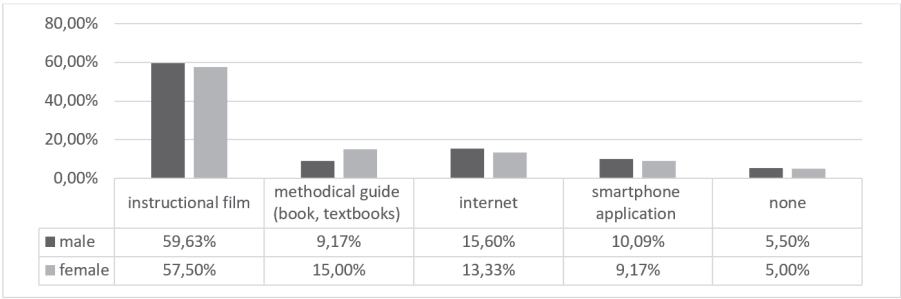
The interest of respondents in further education (Figure 2) is highest in alpine skiing (45.11 %) and snowboarding (23.38 %), with significantly higher interest from female teachers (36.67 %). Only 10.63 % of respondents indicated that they are not interested in further education.

Obrázok 3./ Figure 3.
Spôsob získavania nových informácií z oblasti vyučovania zimných športov; chi - štatisticky významné p<0,01 ($\chi^2_{(4)}$ = 26,478; p=2,533 E-05)./ Method of acquiring new information in the field of teaching winter sports; Chi-square - statistically significant p < 0.01 (χ^2 (4) = 26.478; p = 2.533 E-05).



The largest percentage of respondents (36.35 %) relies on the initiative and teaching materials from universities when acquiring new information in the field of teaching winter sports (Figure 3). The least (10.76 %) draw knowledge from materials provided by national sports federations (associations). The internet and other multimedia sources are also frequently used (29.97 %). A significantly higher percentage of male teachers than female teachers indicated that they do not need such information (22.94 % vs. 4.17 %).

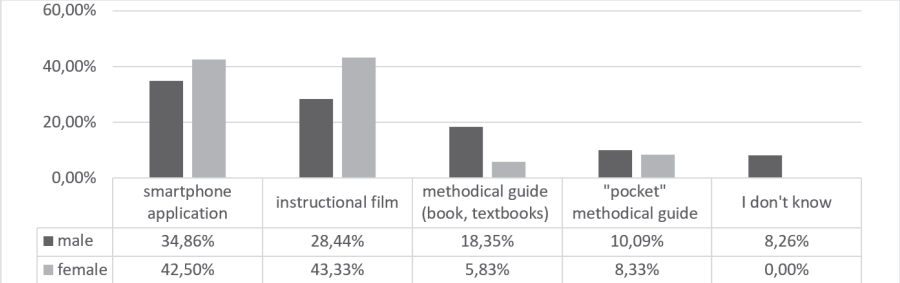
Obrázok 4./ Figure 4.
Najčastejšie využívaný formát študijného materiálu na vyučovanie zimných športov; chi - štatisticky nevýznamné ($\chi^2_{(4)}$ = 1,911; p=0,752)./ The most frequently used format of study materials for teaching winter sports; Chi-square - statistically insignificant (χ^2 (4) = 1.911; p = 0.752).



In the question investigating which format of study material respondents most frequently use to acquire knowledge about teaching winter sports (Figure 4), we found that respondents prefer to use instructional films (58.57 %). All other formats were presented in practically the same proportion.

The question aimed at clarifying current information about which format respondents would currently prefer revealed that the greatest interest is in a smartphone application (38.68 %) and an instructional film (35.89 %). Other formats included a methodical guide (book, scripts) at 12.09 % and a "pocket" methodical guide at 9.21 %. The opinions of female respondents were defined more clearly, as none of them selected the "I don't know" option.

Obrázok 5./ Figure 5.
Záujem o formát študijného materiálu na vyučovanie zimných športov; chi - štatisticky významné $p<0,01$ ($\chi^2_{(4)} = 22,041$; $p=0,0002$)./ Interest in the format of study materials for teaching winter sports; Chi-square - statistically significant $p < 0.01$ (χ^2 (4) = 22.041; $p = 0.0002$).



Discussion

Through our study, we attempted to ascertain current information regarding the level of professional preparedness of teachers who are instructing winter sports in primary schools, with the aim to identify their needs for potential innovation of educational materials. It was confirmed that the majority of respondents expressed interest in further education focused on downhill (alpine) skiing (27.41 %). This preference corresponds with the findings of Hellebrandtová and Roučková (2011), Michal (2006), and others. What we view negatively is the fact that as many as 42.29 % of respondents have not engaged in any activities to enhance their knowledge of winter sports since completing their university studies. Šimonek (2006) states that we can only speak of a modern physical education teacher if they take part in lifelong learning. He emphasizes the importance of personal and social development for teachers, espcially in terms of building their interest in changes in the teaching process and their attitude to self-improvement. We found that female teachers show significantly more interest (36.67 %) in further education than male teachers, and overall, only 10.63 % of respondents indicated no interest in further education. Considering Plastoia's (2017) findings, which highlight that teaching winter sports puts high demands on educators, we believe that the finding that only 10.63% of all surveyed teachers are uninterested in further education can be viewed positively. However, more concerning are our findings that a relatively large percentage of respondents (36.35 %) rely on the initiative and materials from universities, which we consider a positive finding itself, but we view negatively the fact that often-used sources include the internet and other multimedia sources (29.97 %), which may not always meet the required quality, especially if presented by unaccredited or unknown authors (sources). The finding that a significantly higher percentage of male teachers than female teachers stated that they do not need such information (22.94 % vs. 4.17 %) corresponds with existing research on gender differences in attitudes toward sports activities (Kumar Tyagi, Kumar, 2013; Lindstrom, Hanson, Ostergren, 2001; Cigrovski et al., 2014, and others). Questions regarding how teachers would prefer to acquire or format professional and methodological knowledge about winter sports revealed that respondents are motivated to align with current modern trends and express the need to shift from classic instructional films to smartphone applications. We are, of course, aware that this trend is influenced by the teacher's (instructor's) expertise and the quality of their skills (Pighetti, Mateer, Allison, 2022). Majzlík (2017) states that the higher the teacher's engagement in terms of enthusiasm, work ethic, and relationships, the better the students' results. These findings clearly confirm that for winter sports education to progress, teacher training faculties need to increase their engagement in this area. As Masaryková and Antala (2020) suggest, they should reflect challenges from practice and transform them not only into the preparation of future teachers but also into the training of teachers in schools. Similarly, Hardman (2008) states that meeting the needs of teachers requires high quality conceptually and contextually adapted educational programs and teaching materials that can contribute to the teacher being relevantly prepared, adequately and professionally competent. Naturally, this requires respecting the level, character, and stage of the teacher's involvement in the educational process. We believe that this is an opportunity (strategy) through which we can achieve not only the advancement of winter sports education but also the overall improvement of the quality and conditions

of the school physical education process. Our investigation was limited by the fact that we did not manage to get a wider (more representative) sample of respondents, which would more objectively present a view of the possibilities of innovation of the content and method of education of teachers teaching winter sports at the 2nd level of primary schools in Slovakia. The reason is the low interest on the part of male and female teachers to participate in similar surveys.

Conclusion

Our study has the ambition to present the view of teachers teaching winter sports at the 2nd grade of elementary schools on the current problems of their teaching. Through our findings, we want to provide information about how they perceive the quality, conditions and possibilities of professional education in the field of teaching winter sports. We directed our findings to get an answer especially to the question of whether men's and women's opinions on the need for professional education for teaching winter sports differ. Through statistical analysis (Chi-square), we found that there is a significant difference in the approach to this field between male and female teachers, especially from the point of view of interest in further education, in the way of obtaining new information and knowledge, and also in the demand for the format of study material. We were also interested in what is the demand of teachers for a possible innovation of teaching materials for teaching winter sports. We found that there was a significant group of respondents (22.94%) who have a negative attitude towards this area (the answer is "I don't need it"). Of course, the remaining part of the teachers want to see innovation in this area as well and they present the demand that the teaching formats in particular be adapted to the current modern information and communication age and they want the transfer of information from the content of the curriculum to be transformed into a mobile environment. They expressed that they want, in addition to the classic and still quite popular formats of instructional films, to create modern educational applications that can be used in mobile phones.

In conclusion, we would like to express our belief that an important ambition of each advanced society should be the continuous improvement and modernization or innovation of the conditions and possibilities of education, whether for students of teaching faculties or teachers in practice. Every step that improves the teacher's qualities during their professional development is a path to a higher quality of teaching as well as to improving its results for students. It is precisely the subject of physical and sports education that, due to its specific position, aims to ensure that the teacher not only leads the student to master various forms of physical activity, but also provides him with up-to-date information through the format of modern information and communication technologies, which is enormously popular with today's youth. Such a method can to a significantly greater extent enable the student to understand the benefits of a healthy way of life related to physical activity, not only as a necessary, but also as a natural (desired) part of his life.

The presented results of our investigation are part of the research task KEGA 032UMB-4/2022: **"Innovative teaching materials for teachers of physical and sports education at primary schools with a focus on winter seasonal movement activities".**

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VPLYV AKÚTNEJ A INTERMITENTNEJ HYPOXIE NA VÝKON PLAVCOV

THE EFFECT OF ACUTE AND INTERMITTENT HYPOXIA ON THE PERFORMANCE OF SWIMMERS

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Abstract

The main objective of the research was to determine the impact of different forms of hypoxia (acute and intermittent) on the performance of performance swimmers. We realised pre and post-tests in 50-meter freestyle swimming speed (T1), counted the number of breaths taken during 50-meter freestyle swimming (T2), and measured the maximum underwater distance covered in one breath (T3). The study was conducted on a sample of n = 12 performance swimmers (4 females and 8 males), with the average age of 15.75 years, average body weight of 56.2 kg, and average body height of 172.5 cm. The testing was preceded by a 10-minute warm-up and a 400-meter swim using any stroke, followed by two repetitions of a 15-meter sprint and a 35-meter easy swim. The experiment involving hypoxic conditions was carried out over a 3-week period / 21 days in February and March 2024. The participants were randomly assigned to three groups: RG1 underwent hypoxic controlled swimming training, RG2 underwent intermittent simulated hypoxic training using the 'AltitudeTechPortable 2020' hypoxic generator, and RG3 served as a control group without any experimental intervention. The results indicate that the most significant average improvement in T1 was achieved by RG2 (+5.3%), in T2 by RG1 (+35.7%), and in T3 by RG1 (+14.3%). Based on the results, we may conclude that for performance swimmers, acute hypoxia in normoxic conditions, incorporated into swimming training in individual periods of 3 weeks and lasting 10-15 minutes per training session after warm-ups, appears to be most effective, especially when combined with intermittent hypoxia as implemented in this study, particularly for improving performance in the shortest 50-meter disciplines.

Keywords: hypoxia; sports training; performance swimming; swimming performance

Souhrn

Hlavným cieľom realizovaného výskumu bolo odhaliť vplyv rôznych foriem hypoxie (akútnej a intermitentnej) na výkon výkonnostných plavcov. Realizovali sme vstupné a výstupné testovanie v rýchlosti preplávania 50 metrov kraulom (T1), zisťovali počet nádychov pri plávaní 50 metrovej vzdialenosti kraulom (T2) a maximálnej preplávanej vzdialenosti pod vodou na jeden nádych T3. Výskum bol realizovaný na n = 12 výkonnostných plavcoch (4 ženy a 8 mužov), ktorých priemerný vek bol 15,75 roka, priemerná telesná hmotnosť bola 56,2 kg a priemerná telesná výška bola 172,5 cm. Testovanie bolo realizované po 10 minútovom spoločnom rozcvičení a rozplávanie 400 metrovej vzdialenosti ľubovoľným spôsobom a 2 x (15 metrov šprint + 35 metrov vyplávanie). Aplikácie a využívanie hypoxických podmienok prebiehalo v mesiacov február – marec 2024, 3 týždne / 21 dní. Sledovaný probandi boli náhodne rozdelený do 3 súborov, kde VS1 absolvoval plavecký hypoxický kontrolovaný tréning, VS2 absolvoval prerušovaný simulovaný hypoxický tréning pomocou hypoxického generátora „AltitudeTechPortable 2020“ a VS3 absolvoval klasický podnet bez aplikácie experimentálneho podnetu. Výsledky poukazujú na zistenia, že v teste T1 dosiahol najvýraznejšie priemerné zlepšenia VS2 (+ 5,3 %), v teste T2 dosiahol najvýraznejšie zlepšenia VS1 (+ 35,7 %) a v teste T3 sa najviac zlepšil VS1 (+ 14,3 %). Na základe výsledkov môžeme konštatovať, že pre plavcov výkonnostnej úrovne sa javí ako najefektívnejšie využívať akútnu hypoxiu v normoxických podmienkach zaraďovaný do plaveckej

prípravy v jednotlivých obdobiach v dĺžke 3 týždňov a rozsahu 10-15 minút v tréningovej jednotke po rozcvičení a rozplávaní, ideálne v kombinácii s intermitentnou formou hypoxie podľa realizovanej schémy v tomto výskume najmä pre zlepšenie času v najkratších 50 metrových disciplínach.

Klíčová slova: hypoxia; športový tréning; výkonnostné plávanie; plavecký výkon

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Introduction

There are currently numerous options for improving swimming performance, allowing coaches to select the most optimal ones for each individual athlete. Hypoxic training in its various forms is an under-utilised method of training in performance swimming. While acute hypoxia, characterized by controlled breathing in normoxic conditions, is a common practice among swimmers, other forms of hypoxic training remain less frequently employed. Reasons may include higher financial costs involved, the need for long-term application, or the more demanding organizational requirements associated with high-altitude training, the relative complexity of using hypoxic tents, masks, and chambers, as well as the relatively lower number of studies on the effects of these forms of hypoxia on specific swimming performance. When comparing hypoxia and swimming performance, it is essential to consider the specific form of hypoxia, as recent research has shown that different forms of hypoxia and the extent to which they affect swimming performance vary (Hamlin & Hellemans, 2003; Rodriguez et al., 2004; Bonetti & Hopkins, 2009; Hamlin et al., 2010; Suchý, 2011; Woorons, et al., 2014).

The primary reason is the potential to delay the onset of oxygen debt and lactate accumulation in the muscles, as well as to optimize the ability to prolong underwater time on one breath, reduce the number of breaths and the time required to complete swimming disciplines. Cardelli et al. (2000) who reported a time loss of 1.46% when taking a breath every four strokes at 25 meters and 3.14% when taking a breath every second stroke, representing a significant time loss considering the distance covered, support these findings.

Hypoxic training equipment can be incorporated into the training process essentially anytime and anywhere. The idea behind the use of simulated intermittent hypoxic preparation is to replace breathing normal air with oxygen-reduced air. According to Pupiš and Korčok (2007), equal intervals of normoxia and hypoxia are used in a 5:5 ratio. To enhance athletic performance, a model of 6 - 10 x 5 minutes of hypoxia and 5 minutes of normoxia, 1 - 2 times a day, ideally for 21 days, is also used. However, the simulated altitude is variable and is determined based on oxygen saturation values, ideally between 75-80%. For a positive effect, it is recommended to undergo the process for at least 90-180 minutes a day or every other day (Hellemans, 1999). However, the body's response to hypoxic conditions is individual and can vary significantly across a range of parameters (Ferritty, 2010). Suchý a Dovalil (2011) and Czuba et al. (2018) warn that this can lead to a faster onset of fatigue, overtraining and even burnout, which are considered very negative phenomena in sports training. The authors also emphasise the need to monitor physiological and biochemical parameters, most commonly by tracking heart rate and metabolic response. Dívald (2009) stresses the importance of pre-hypoxia medical evaluations. The most common methods include heart rate monitoring and performance testing in the specific sport.

Czuba et al. (2011) and Roels et al. (2007) specifically direct the use of intermittent hypoxic training towards improving anaerobic capacity and sprint performance. It is necessary to mention that training hypoxia is nowadays abandoned for several reasons. The most important reason is the increased likelihood of overloading the body, often leading to overtraining. In addition, it is necessary to realize that the load itself decreases the oxygen saturation of the blood, while using hypoxic simulation we can reduce the saturation, but the accompanying phenomenon is a significant reduction in the intensity of the load or even even the interruption of activity due to lack of oxygen. Thus, training efficiency may be reduced, while other physiological benefits have not been clearly described (Rodriguez et al., 1999; Garcia et al., 2000; Pupiš, 2014). We will aim to confirm these studies and expand our understanding of its applications and effects on selected swimming parameters.

The research was carried out with the support of GÚ VEGA1/0547/22 The use of hypoxia and hyperoxia in sports training.

Aim

The aim of the research was to uncover the impact of various forms of hypoxia on the performance of performance swimmers.

Method

We opted for three tests. In test T1, the swimmers performed a 50-meter freestyle swim at maximum speed. Test T2 focused on breath count during a 50-meter swim. In the third test, T3, swimmers completed a maximum underwater distance in one breath. Prior to testing, all participants completed a warm-up consisting of a 400-meter swim using any stroke and 2 x (of a 15-meter sprint + a 35-meter easy swim). The participants were given a 10-minute overview of the tests and their objectives.

T1: 50-meter freestyle swim at maximum speed – dive start at the signal. Participants completed the test twice and the results show the best time achieved. The goal was to complete the distance as quickly as possible while minimizing the number of breaths taken. The participants had a 10-minute rest period between attempts.

T2: Stroke count during a 50-meter freestyle swim - three examiners counted the number of strokes during the previous trial. The number of strokes from both attempts was counted and the data from the faster attempt was recorded.

T3: Maximum underwater distance covered in one breath - the objective was to swim the longest possible distance underwater, with a grab start from the edge (turning board), in a single breath. The participants were instructed to complete the test underwater without surfacing and were allowed two attempts. The participants rested for 10 minutes between attempts. We recorded the longer distance achieved.

Tabuľka 1./ Table 1.
Hypoxický tréningový plán – normoxia realizovaný na VS1./ Hypoxic training plan – normoxia, group RG1.

Week	Monday	Wednesday	Friday
1.	2x25m H (breaststroke) with 25m easy swim 2x50 m BC 3-5-7 2x50 m BC 5-7-9 2x25m F (with breathing restriction)/without breathing 2x25m sprint without breathing F	2x25m H (dolphin kick + fins) 2x50 m BC 3-5-7 2x50 m BC 5-7-9 2x25m F (with breathing, first breath after 15m sprint) 2x25m sprint without breathing F	4x25 m H (Breaststroke) 4x50 m BC 3-5-7 4x50 m BC 5-7-9 2x25m sprint without breathing F (fins)
2.	4x25 m H (dolphin kick + fins) 4x25 m BC 5-7-9 4x25m F (with breathing restriction) breathing after 12,5m 2x25m + turn - sprint without breathing F (fins)	4x25 m H (Breaststroke) 6x25m FK (with breathing restriction, 1 breath after 12,5m) 3x50m F (breathing every 5 strokes) 2x50m sprint without breathing F (fins)	6x25 m H (dolphin kick + fins) 6x50 m BC 5-7-9 4x25m FK (with breathing restriction, 1 breath after 15m) 2x50m sprint without breathing F (fins)
3.	4x25 m. H (dolphin kick + fins) 4x50 m. BC 7-9 4x25m FK (with breathing restriction, 1 breath after 15m) 2x50m sprint without breathing F (fins)	6x25 m H (Breaststroke) with start 2x100 m BC 3-5-7 4x50m sprint without breathing F (fins)	4x25 m H (Breaststroke) 2x100 m BC 7-9 4x25m FK (with breathing restriction, 1 breath after 15m) 4x50m sprint without breathing F (fins)

⋆*Legend.* FK – Freestyle kick, BC – Breath control, H – Hypoxia (Single-breath underwater swim), F – Freestyle, B – Breaststroke

The study was conducted on a sample of n = 12 performance swimmers (4 females and 8 males), with the average age of 15.75 years, average body weight of 56.2 kg, and average body height of 172.5 cm. The tests took place during the months of February - March 2024, 4 weeks / 28 days. The

post-tests were carried out 7 days after the end of the application of the experimental stimuli. The participants were randomly divided into 3 groups. Research group 1 (RG1) completed swimming-based hypoxic controlled training, research group 2 (RG2) underwent intermittent simulated hypoxic training using the 'AltitudeTechPortable 2020' hypoxic generator, and research group 3 (RG3) received a classic stimulus without the application of any experimental stimulus.

RG1: experienced a classical training stimulus combined with acute hypoxic training. Table 1 shows the training programme that the participants followed for 21 days, 3 times a week for 10-15 minutes after a warm-up swim at the beginning of the training session. In this set there were 3 men and 1 woman included in the group of performance swimmers.

RG2: In this set there were 3 men and 1 woman included in the group of performance swimmers.. Experienced a classical training stimulus combined with simulated intermittent hypoxic training using the 'AltitudeTechPortable 2020' hypoxic generator. The application period was 21 days. For the first 7 days, the simulated altitude was 3500-4000 meters above sea level, with oxygen saturation maintained between 88-90%.

Hypoxia was applied in cycles of 5 min with mask and 5 min without mask, as follows:

- 1. day 6 cycles,
- 2. day 7 cycles,
- 3. day 8 cycles,
- 4.-6. day 9 cycles,
- 7. day off

On days 8-14, the altitude was adjusted according to saturation, aiming to keep it between 85 - 88%. Hypoxia was applied in cycles of 6 min with mask and 4 min without mask, as follows:

- 1.-6. day 9 cycles,
- 7. day off

For the last 7 days (days 15-21), saturation was maintained below 85% but not below 80%. Simulated altitude was adjusted accordingly. The participants were breathing for 6 min with mask and 3 min without mask as follows:

- 1.-6. day 10 cycles,
- 7. day off

RG3: experienced classical training stimulus without any experimental stimulus, meaning that their 'classical' swimming training did not include swimming exercises with controlled breathing or underwater swimming with breath holding. In this set there were 2 men and 2 women included in the group of performance swimmers.

The research groups (RG1, RG2, and RG3) completed the following during the observation period:

- Morning swimming training – 1.5 hours 5 x Per Week
- Afternoon swimming training – 1 hour 3 x Per Week
- Gym - 1 hour 3 x Per Week

Diagnostic We selected three specific swimming performance tests for our study.

T1: Swimming 50 meters freestyle at maximum speed

- The goal was to complete the specified distance as quickly as possible while minimizing the number of breaths. The participants had two attempts. Between attempts, the participants had a 10-minute rest period. The results show the better performance.

T2: Breath count during a 50-meter freestyle swim

- We measured the stroke count for each attempt and selected the data from the faster one. Between attempts, the participants had a 10-minute rest period.

T3: Maximum distance swam underwater on one breath

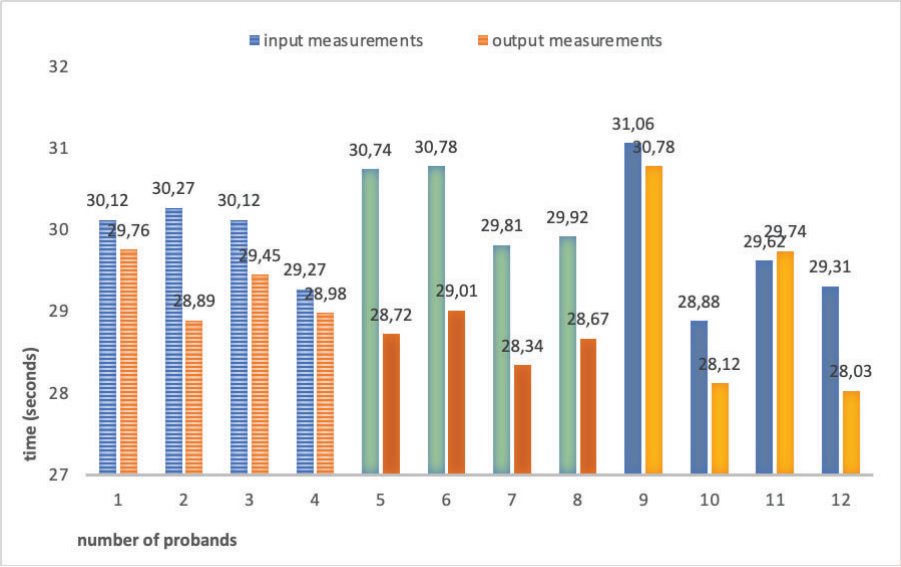
- The goal was to swim (Breaststroke, dolphin kick) the longest distance underwater on one breath, with a grab start from the edge (turning board). A 10-minute rest was given between attempts. The results show the longer distance achieved.

Given the number of participants in each research group, the results were analysed and evaluated using basic qualitative methods (analysis, synthesis, induction, deduction, comparison, case study) and basic quantitative methods (mean, variation range, percentage).

Results

The results of the three tests are presented in the following section. Figure 1 shows the individual results of the participants in test T1: swimming 50 meters freestyle at maximum speed. Table 2 summarizes the results using fundamental statistical and mathematical analysis. Figure 2 shows the individual results of the participants in test T2: the number of breaths during the 50 m freestyle swim. Table 3 presents the results of this test using basic mathematical and statistical methods. Figure 3 and Table 4 present the results of test T3: Maximum distance swam underwater on one breath.

Obrázok 1./ Figure 1.
Výsledky testu T1 (plávanie 50 metrov kraulom max.rýchlosťou)./ Results of test T1 (Swimming 50 meters freestyle at maximum speed).



In Figure 1 we can see that in research group 1, 11 participants showed improvement. The most significant improvement was observed in participant 5, who improved by 2.02 seconds. This participant exhibited the most notable improvement, likely due to feeling positive effects under the experimental stimulus of intermittent hypoxia, which he described as a light yet powerful stroke when swimming. The only decrease in performance was observed in a participant from RG3 (participant 11), who reported feeling cold, weak, and with reduced energy during the training process for the last 3 days before the test.

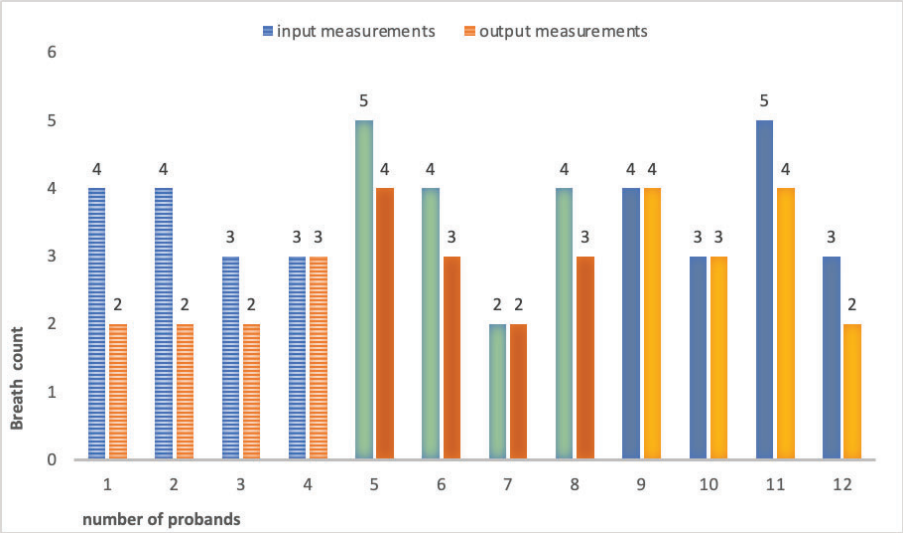
In Table 2, we present the qualitative results of test T1 using basic mathematical and statistical data. It is clear that the best percentage improvement was recorded in RG2, where the average improvement due to hypoxic training was 5.30% (the average improvement due to intermittent hypoxia and classical swimming training stimulus was 1.62 seconds). In research group 1 (RG1), we recorded an average improvement of 2.27% (the impact of acute hypoxia and swimming training was 0.68 seconds),

and in RG3, an improvement of 1.85% (improvement of 0.55 seconds). The improvement resulting from the 'classical swimming training', which all participants underwent, indicates the direct impact on the mean values of 0.42% in RG1 and 3.45% in RG2.

Tabuľka 2./ Table 2.
Kvantitatívne ukazovatele výsledkov testu T1./ Quantitative indicators of T1 test results.

TEST 1 50 RG (seconds)	**RG 1**		**RG 2**		**RG 3**	
Min	29,27	28,89	29,81	28,34	28,88	28,12
Max	30,27	29,76	30,78	29,01	31,06	30,78
mean	29,95	29,27	30,31	28,69	29,72	29,17
SD	0,39	0,35	0,45	0,24	0,82	1,15
median	30,12	29,21	30,33	28,7	29,46	28,93
average improvement		0,68		1,62		0,55
average % improvement		2.27%		**5.30%**		1.85%

Obrázok 2./ Figure 2.
Výsledky testu T2 (Počet nádychov na 50 metrov voľným spôsobom)./ Results of test T2 (Count of breaths during a 50-meter freestyle swim).



In Figure 2, we present the results of test T2 monitoring changes in the number of breath count during a 50-meter freestyle swim compared to the previous test. The most significant reduction in breath count was observed in two participants from RG1 and one participant from RG2, decreasing their breath count by two. The other participants showed a decrease of one breath, contributing to a faster 50-meter swim time.

Tabuľka 3./ Table 3.
Kvantitatívne ukazovatele výsledkov testu T2./ Quantitative indicators of T2 test results.

TEST 2: Breath Count	**RG 1**		**RG 2**		**RG 3**	
Min	3	2	4	2	3	2
Max	4	3	5	4	5	4
mean	3,5	2,25	3,75	3	3,75	3,25
SD	0,5	0,43	1,09	0,71	0,83	0,83
median	3,5	2	4	3	3,5	3,5
average improvement		1,25		0,75		0,5
average % improvement		**35.70%**		20.00%		13.30%

In Table 3, we present the results in the form of basic quantitative mathematical and statistical data. The most significant mean improvement achieved RG1, with a 35.7% increase (an average of 1.25 breaths). Research group RG2 exhibited a mean improvement of 20% (0.75 breaths), while RG3 demonstrated a mean improvement of 13.3% (0.5 breaths).

In Table 3, we present the results in the form of basic quantitative mathematical and statistical data. The most significant mean improvement achieved RG1, with a 35.7% increase (an average of 1.25 breaths). Research group RG2 exhibited a mean improvement of 20% (0.75 breaths), while RG3 demonstrated a mean improvement of 13.3% (0.5 breaths).

Obrázok 3./ Figure 3.
Výsledky testu T3 (max. vzdialenosť plávaná pod vodou na jeden nádych)./ Results of test T3 (Maximum distance swam underwater on one breath).

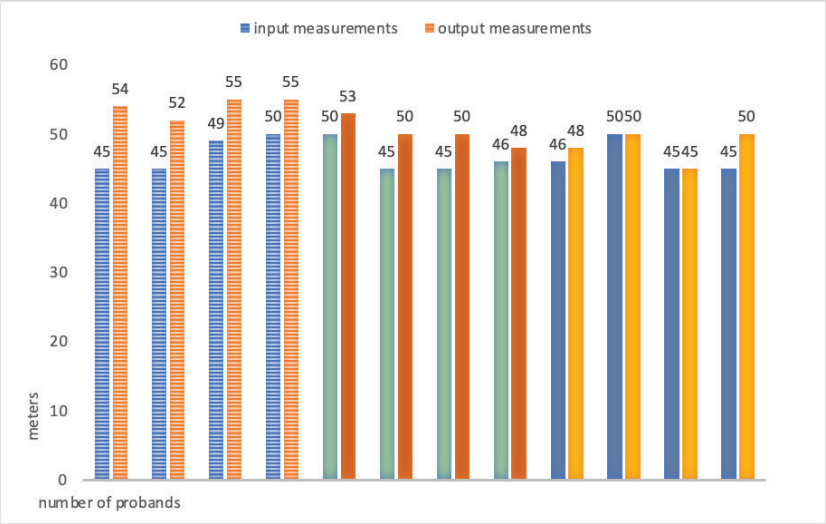


Figure 3 shows the results recorded in test T3, where the participants were instructed to cover maximum distance underwater in one breath using breaststroke. The longest swimming distance was recorded in the post-test measurements for participants 3 and 4 in RG1 (55 meters). The shortest distance was recorded in the pre-tests for participants 1 and 2 in RG1, participants 6 and 7 in RG2, and participants 9 and 12 in RG3 (all of them covering a distance of 45 meters). In the post-test measurements, the shortest swimming distance was achieved by participant 11 from RG3, who was the only participant to show no improvement. However, this is the only participant who did not show any improvement in test T1 either.

Tabuľka 4./ Table 4.
Kvantitatívne ukazovatele výsledkov testu T3./ Quantitative indicators of T3 test results.

TEXT 3 Max distance covered underwater (meters)	**RG 1**		**RG 2**		**RG 3**	
Min	45	52	45	48	45	45
Max	50	55	50	53	50	50
mean	47,25	54	46,5	50,25	46,5	48,25
SD	2,27	1,22	2,06	1,79	2,06	2,04
median	47	54,5	45,5	50	45,5	49
average improvement - difference		6,75		3,75		1,75
average % improvement		**14.29%**		8.06%		3.76%

Table 4 summarizes the qualitative findings, revealing that RG1 achieved the greatest mean improvement of 14.29% (6.75 meters). Improvement was also observed in the research group RG2 by 8.06% (3.75 meters) and in RG3 by 3.76% (1.75 meters). When comparing the data and excluding

the influence of classical swimming training, we assume that the effect of acute hypoxia led to an improvement of 5 meters and the effect of intermittent hypoxia led to an improvement of 3 meters in the average results of the participants.

Discussion

The impact of different forms of hypoxia on performance swimming appears to be positive, as our observations have revealed improvements in the monitored parameters. Upon analyzing the individual participant data, excluding participant 13 from group 3 (the only one who did not improve or showed minimal improvement due to illness during the study), the results consistently demonstrate a positive impact on all measured parameters, including 50-meter freestyle performance, breath count in the T1 test, and maximum underwater swimming distance.

In our research, we implemented the use of IHT over an application period of 21 days, where for the first 7 days the altitude was simulated at 3500-4000 m a.s.l. and saturation was maintained at between 88-90%. Hypoxia was implemented in cycles of 5 min with mask and 5 min without mask. The authors Garcia et al. (2000) performed IHT for 120 min/day for 5 days of IHT/at a simulated altitude of 3800 m.a.s.l. and Piel-Aulin et al. (1998) for 12 h for 10 days of IHT/at a simulated altitude of 2000-2700 m.a.s.l. They observed a significant increase in the proportion of reticulocytes, which should be a clear evidence of erythropoiesis. Similar results were found by Rodriguez et al. (1999), where a nine-day exposure to IHT/at a simulated altitude of 5000 m.a.s.l. induced a significant increase in red blood cell count, reticulocyte proportion and haemoglobin concentration, again indicating increased erythropoiesis. All the above studies confirm our results and Lianshi (2004), which confirm the positive effect of IHT.

Contradictory to our findings are studies that, on the contrary, have found no significant changes in sports performance (Martino, Myers, & Bishop, 1995; Vallier et al., 1996; Frey et al., 2000, Levine, 2002).

With this in mind, it is important to note the limitations of the research, the largest of which was the relatively small number of swimmers, where it was difficult to recruit a group of swimmers with similar performance. Ideally, the research would be carried out on a larger sample and, if possible, the effects of a combination of several of the stimuli studied, acute hypoxia together with classical swimming training and simulated intermittent hypoxia would be identified and analysed. Future research could compare our results with studies using hypoxia at higher altitudes, such as living at a lower altitude and training at a higher altitude, or vice versa.

Conclusion

Based on our results, we can conclude that both forms of hypoxia, acute and simulated intermittent hypoxia, have a beneficial effect on the measured parameters. Simulated intermittent hypoxia appears to be more beneficial for improving performance in short 50-meter freestyle disciplines. Conversely, acute hypoxia, which can be applied into swimming training, demonstrates greater effectiveness in reducing breathing rate and increasing underwater distance covered in a single breath.

Any expectations in terms of the positive impact of hypoxic training, especially for increasing erythropoiesis, improving endurance training and increasing VO2max depend significantly on the choice of the type and form of hypoxia as well as the duration of exposure of the body in a hypoxic environment (number of days or weeks as well as the number of hours per day. Based on the results, we evaluate our research as positive and useful for swimming training practice.

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POROVNÁNÍ TRADIČNÍCH A INOVATIVNÍCH TESTŮ SVALOVÉ ZDATNOSTI

COMPARING AND CONTRASTING TRADITIONAL AND INNOVATIVE MUSCULAR FITNESS TESTING

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Abstract

Muscular fitness is a key component of health, and its accurate assessment is crucial. Due to developments in the field of fitness, there is an increasing need to explore new testing methods tailored to specific conditions and demographic groups. This pilot study focuses on the correlation between traditional and innovative muscular fitness tests, emphasizing their substitutability in a healthy adult population. The study compares established tests such as handgrip strength, push-ups, sit-ups, and standing long jump with innovative tests, specifically dynamometry for assessing the back and legs, squats, and medicine ball throws. The research sample included healthy males and females ($n = 36$) with an average age of 21.3 years. Correlational analysis using Pearson's correlation coefficient revealed a significant positive correlation between handgrip strength and dynamometry of the back and legs ($r = 0.842$, $p < 0.01$), suggesting that these tests assess complementary aspects of muscular strength. Similarly, the medicine ball throw showed a strong correlation with handgrip strength ($r = 0.805$, $p < 0.01$), indicating its effectiveness in assessing explosive strength. In contrast, squats showed a weak correlation with traditional endurance tests, such as sit-ups ($r = 0.125$, $p > 0.05$), indicating the involvement of different muscle groups and aspects of endurance. The identified correlations highlight the complex nature of muscular fitness, where innovative tests may only partially replace traditional methods. However, further research with larger and more diverse samples is needed to confirm these preliminary findings.

Keywords: strength; muscular endurance; fitness assessment

Souhrn

Svalová zdatnost představuje klíčovou složku zdraví, jejíž přesné hodnocení je zásadní. Vzhledem k vývoji v oblasti fitness narůstá potřeba zkoumat nové testovací metody, přizpůsobené specifickým podmínkám a demografickým skupinám. Tato pilotní studie se zaměřuje na korelaci mezi tradičními a inovativními testy svalové zdatnosti, s důrazem na jejich zastupitelnost u zdravé dospělé populace. Studie srovnává zavedené testy, jako jsou síla stisku ruky, kliky, leh-sedy a skok do dálky z místa, s inovativními testy, konkrétně dynamometrií pro hodnocení zad a nohou, dřepy a hodem medicinbalem. Výzkumný vzorek zahrnoval zdravé muže a ženy ($n = 36$) s průměrným věkem 21,3 let. Korelační analýza pomocí Pearsonova korelačního koeficientu ukázala významnou pozitivní korelaci mezi stiskem ruky a dynamometrií zad a nohou ($r = 0{,}842$, $p < 0{,}01$), což naznačuje, že tyto testy hodnotí komplementární aspekty svalové síly. Podobně hod medicinbalem vykazoval silnou korelaci se silou stisku ruky ($r = 0{,}805$, $p < 0{,}01$), což poukazuje na jeho efektivitu při hodnocení explozivní síly. Naopak dřepy vykázaly slabou korelaci s tradičními vytrvalostními testy, jako jsou sedy-lehy ($r = 0{,}125$, $p > 0{,}05$), což naznačuje zapojení odlišných svalových skupin a aspektů vytrvalosti. Zjištěné korelace podtrhují komplexní povahu svalové zdatnosti, kde inovativní testy mohou tradiční metody jen částečně nahradit. Pro potvrzení těchto předběžných zjištění je však zapotřebí dalšího výzkumu na větších a rozmanitějších vzorcích.

Klíčová slova: síla; svalová vytrvalost; hodnocení zdatnosti

Introduction

The paradigm of muscular fitness has evolved in contemporary society, reflecting changes in anthropometric measurements and performance related to physical fitness. Muscular fitness is no longer just a reflection of individual health but a complex interplay of physiological attributes with far-reaching implications for public health. Increasingly, evidence highlights the substantial role of muscular fitness in mitigating the risk of chronic diseases, including cardiovascular and metabolic disorders (Loprinzi, 2018). Furthermore, muscular fitness has emerged as an independent predictor of all-cause and cancer mortality (Artero et al., 2012).

Muscular fitness can also be assessed through measures of muscular strength and muscular endurance. Muscular strength refers to the maximal force that a muscle or muscle group can generate, while muscular endurance refers to the ability of a muscle group to perform repeated contractions over a specific period of time (Bohannon, 2019). Additionally, a physical fitness assessment may include measures of body composition, cardiorespiratory endurance, and musculoskeletal flexibility (Appelqvist-Schmidlechner et al., 2020). These assessments can provide valuable information about an individual's overall muscular fitness and help identify areas for improvement (Cuenca-Garcia et al., 2022).

The importance of muscular fitness extends into early adulthood, with associations noted between muscular strength and a plethora of health outcomes, including quality of life, academic and workplace success, and even mental health (Appelqvist-Schmidlechner et al., 2020; Vaishya et al., 2024). As sedentary lifestyles become more prevalent, especially within Western societies, the accompanying decline in muscular strength and fitness presents a multifaceted challenge to health (Silva et al., 2020). Thus, our study focuses on the adult population, particularly young adults, to discern the relationship between muscular fitness and a spectrum of health indicators.

Traditional methods of measuring muscular fitness in adults, such as hand-grip strength, push-ups and the standing broad jump, serve as benchmarks within the field (Bohannon, 2019). These conventional tests are complemented by the assessment of endurance, alongside other components of physical fitness (Castro-Piñero et al., 2021). However, the pursuit of novel and possibly more appropriate methods for specific contexts or populations necessitates a continuous search for innovation in fitness testing (Ojeda et al., 2020).

Despite the widespread use of traditional fitness tests, their limitations are apparent, necessitating the exploration of alternative assessments. The validity of the push-up test, a common measure of upper body muscular endurance, remains unconfirmed, with a paucity of evidence supporting its use for this purpose (Castro-Piñero et al., 2021). In line with these findings, the push-up test has also been criticized for its low reliability (Cuenca-Garcia et al., 2022), further underscoring the need for more robust and accurate measures of muscular fitness. Moreover, the handgrip strength test may yield misleading results concerning health outcomes; a study by Cooper et al. (2022) revealed an incongruous positive relationship between body mass index (BMI) and handgrip strength, suggesting that the test might not adequately reflect cardiovascular health risks. This burgeoning recognition of the deficiencies in traditional testing propels the search for more suitable tests, capable of providing a reliable and holistic evaluation of muscular strength and endurance.

The congruence or disparity between traditional and novel tests is pivotal; determining their substitutability or the need for their combination according to situational demands forms a core objective of this research. The rationale lies in the hypothesis that a multi-faceted approach, targeting different body parts and varying in load (e.g., press vs. pull), may provide a more holistic understanding of muscular fitness (Cuenca-Garcia et al., 2022). While laboratory measurements are well-established, field tests offer practicality and versatility, catering to individual and sample-specific nuances (Cooper et al., 2022).

The authors are not aware of any sources that directly analyse multiple alternative tests of muscular fitness. Our research aims to compare traditional and innovative muscle fitness tests to evaluate their potential substitutability and to establish whether a combination of these assessments could provide a comprehensive profile of muscular fitness. The findings aim to contribute to the body of knowledge on physical fitness assessment and its implications for health and society.

Methods

The research conducted was a pilot study, designed to establish preliminary data on the feasibility and potential effectiveness of the chosen test protocols for assessing muscular fitness. This foundational phase is essential for refining research methods, validating testing procedures, and identifying any logistical or methodological challenges that may arise in a larger scale study. Data obtained from this initial investigation will be used to inform and structure future rigorous investigations, with the ultimate goal of enhancing the reliability and validity of fitness assessments in diverse populations. Furthermore, the pilot nature of the study allows for the exploration of participant response to the test battery, thus contributing to the development of standardized protocols that can be replicated in subsequent studies.

The term "traditional tests" encompasses a set of evaluations that have been long-established and widely utilized across various age groups and continents for the measurement of muscular fitness. These include exercises such as push-ups, sit-ups, standing broad jump, and handgrip dynamometry. Conversely, "innovative" tests are those that have been employed less frequently, with a comparatively weaker body of evidence to support their efficacy, including squats, medicine ball throws, and back-leg dynamometry. These tests are not entirely new or unique; for instance, medicine ball throws are common among children but not as prevalent within adult populations. The selected tests were chosen for their analogous nature in terms of targeted body areas (upper/lower body), type of exertion (strength endurance, absolute strength), allowing for an examination of their theoretical interchangeability in fitness assessment.

Participants

The research sample comprised healthy male and female participants (n = 36), with an average age of 21.3 years. Considering the nature and objectives of the research, it was deemed unnecessary to stratify participants by gender. Individuals with a BMI over 30 (kg/m^2) were excluded from the study to maintain a focus on a population representative of standard health parameters. The participants were well-informed about the research procedures and objectives, ensuring informed consent. The group's mean weight was 76.4 kg (SD = 14.2 kg), and an average height 177.25 cm (SD = 11.0 cm). The study was conducted in accordance with the latest version of the Declaration of Helsinki.

Testing

Anthropometric data were collected with participants' unshod and dressed in lightweight attire. Body weight was determined using an electronic scale (model HN-289, Omron, Japan). Body height was measured using a stadiometer (SECA model 220, Hamburg, Germany). BMI was subsequently computed as the weight in kilograms divided by the square of height in meters (kg/m^2).

To evaluate muscular fitness, seven specific tests were administered, aimed at gauging relative and absolute strength as well as dynamic muscular performance for both upper and lower body. The selected assessments included: squats, push-ups, sit-ups, standing broad jump, medicine ball throw, handgrip dynamometry (model MAP 80K1S, KERN, Kern & Sohn GmbH, Germany), and pulling back-leg dynamometry (model SH5007, Saehan Dynamometer, Saehan Corporation, India).

The testing took place within a single session. A general 10-minute full-body warm-up and technical rehearsal of the tests preceded the actual measurements. A warm-up started with dynamic stretching, like leg swings and arm circles, to activate muscles and improve mobility. This is followed by light cardio (e.g., jogging and jumping jacks) to raise the heart rate and increase blood flow; and bodyweight exercises, such as squats and lunges, further engage key muscles. Participants had two to three attempts for each test, with the best performance being recorded. For the strength endurance tests (squats, push-ups, sit-ups), there was only one attempt. A minimum 5-minute rest was allotted between tests. The order of tests was strategically chosen to ensure that fatigue from preceding activities did not adversely affect subsequent performances: handgrip, standing broad jump (SBJ), medicine ball throw (MBT), back-leg, sit-ups, push-ups, and squats.

Standing broad jump (SBJ)

Participants positioned themselves with feet together, behind a demarcated starting line. They were permitted to use a countermovement or arm swing to facilitate the jump. The objective was to land with both feet simultaneously, stabilizing immediately upon landing without any additional

forward movement. If the participant fell backward or made contact with the ground with any other body part, a repeat attempt was granted. Measurement of the jump distance was executed using a tape measure, extending from the starting line to the heel of the foot nearest to the starting line upon landing.

Push-ups

The participant initiated the exercise in a standard push-up position: hands and toes were in contact with the floor, the body extended in a straight line from head to heels, feet set apart marginally, and arms spaced shoulder-width with full extension, forming a perpendicular line to the torso. Maintaining a rigid back and legs, the participant then lowered their body and touch the floor with chest only. A repetition was counted once the participant returned to the starting position. The objective was to execute the maximal number of repetitions without repositioning the hands or toes throughout the duration of the test.

Squats

The standard for the squat was established as a deep squat, which necessitates the descent of the upper part of the hip joint below the level of the knee cap (patella), often referred to as a "squat below parallel“. In the upper position, participants were required to achieve full extension, which was monitored for compliance in the knee and hip joints, as well as an upright posture. The width of the stance was not specified, allowing participants to choose a position that felt natural and comfortable, providing flexibility for individual biomechanical differences. Similarly, there was no requirement regarding the position of the arms, allowing them to remain in a position most conducive to maintaining balance and proper form throughout the test. The requirement was to perform the maximum number of repetitions for a duration of two minutes.

Sit-ups

Participants started in a supine position with hands on their shoulders and knees bent at 90 degrees. Ankle support was provided by a researcher. Subjects curled up to touch their knees with both elbows and then reclined until the shoulder blades contacted the mat, completing one repetition. The total count of repetitions within a 60-second period was documented.

Medicine ball throw (MBT)

Subjects initiated the exercise standing with feet parallel, holding a 6 kg, 40 cm diameter medicine ball at chest height using both hands with elbows flexed. The ball was propelled forward by both hands without any rotational movement of the trunk, preceded by a countermovement. The throw distance was quantified from the initial impact point of the ball to the throwing line.

Handgrip dynamometry (handgrip)

Grip strength was measured in a standing position with the shoulder adducted and flexed elbow. Participants performed two attempts with each hand, and the best result from the individual measurements was recorded.

Pulling back-leg dynamometry (back-leg)

The subject assumed a standing position on the apparatus with feet placed together and grasped the handle with both hands. The handle's height was adjusted to align with the subject's knees, and the chain was positioned to pass between the legs, mimicking a partial deadlift motion. It was necessary that the handle did not contact the thighs during the lift.

Statistical Analysis

Descriptive statistics for our dataset was generated using IBM SPSS software, version 20. Within this analytical framework, we also calculated the Pearson rank correlation coefficient to evaluate the strength of association between the variables collected. Following the guidelines suggested by Abbott (2011), the magnitude of the correlation was classified as follows: coefficients of 0.8 or higher were indicative of a very strong relationship; values between 0.6 and 0.8 signalled a strong relationship; coefficients ranging from 0.4 to 0.6 pointed to a moderate relationship; figures from 0.2 to 0.4 were

considered a weak relationship; and coefficients below 0.2 were interpreted as a very weak relationship. For the measured values, a test for normality of the data was performed (Shapiro-Wilks).

To elucidate the comprehensive relationship between traditional and innovative muscular fitness tests, comparative analyses were conducted between these two categories. The connection established between the test batteries is not officially recognized but was constructed for the purpose of determining the potential substitutability of the selected tests. Performance rankings were created for participants within each individual test and for the overall test battery. These rankings facilitated the establishment of two separate hierarchies for traditional and innovative tests, respectively. The relationship between these hierarchies was then statistically evaluated to assess the degree of correlation and potential for one category of tests to serve as representative of the other. The ordering of participants' performances in each test was analysed to investigate the relationship between the two categories. Upon statistical examination, a Pearson rank correlation was applied.

Results

Physical fitness assessments were conducted on a group of individuals, resulting in a comprehensive data set including various measures of muscular strength and endurance (Table 1). The mean weight and height of participants were 76.38 kg (SD = 14.16 kg) and 177.25 cm (SD = 11.00 cm), respectively. In assessing handgrip strength, the mean force generated was 48.72 kg (SD = 11.86 kg). The mean force level on the back-leg showed 151.89 kg (SD = 41.32 kg).

For the muscular endurance tests, participants performed an average of 24.06 push-ups (SD = 12.04 repetitions), reached 228.28 cm (SD = 29.00 cm) in the SBJ, and MBT an average distance of 7.25 meters (SD = 1.57 meters). In the sit-up test, an average of 42.64 repetitions (SD = 5.10 repetitions) was observed, and for the squats performed within 120 seconds, the mean was 82.58 repetitions (SD = 12.24 repetitions).

Tabulka 1./ Table 1.
Průměrné hodnoty vybraných somatických charakteristik a výsledky jednotlivých testů./ Average values of selected somatic characteristics and results of individual tests.

	N	Weight (kg)	Height (cm)	Handgrip (kg)	Back-leg (kg)	Push-ups (N)	SBJ (cm)	MBT (cm)	Sit-ups (N)	Squats (120s) (N)
Mean	36	76.4	177.3	48.7	151.9	24.1	228.3	7.3	42.6	82.6
SD	36	14.2	11.0	11.9	41.3	12.0	29.0	1.6	5.1	12.2

Note. Handgrip= force measured in kg (equivalent to N); SBJ= Standing broad jump; MBT= Medicine ball throw

Tabulka 2./ Table 2.
Výsledky korelační analýzy pro somatické charakteristiky a jednotlivé testy./ The results of the correlation analysis for somatic characteristics and individual tests.

		Weight	Height	Handgrip	Back-leg	Push-ups	SBJ	MBT	Sit-ups	Squats
Weight	Pearson Correlation	1	.787⋆⋆	.786⋆⋆	.760⋆⋆	0.264	.510⋆⋆	.749⋆⋆	0.179	-0.275
	Sig. (2-tailed)		0.000	0.000	0.000	0.120	0.001	0.000	0.296	0.122
Height	Pearson Correlation	.787⋆⋆	1	.615⋆⋆	.640⋆⋆	0.179	.625⋆⋆	.667⋆⋆	0.094	-.436⋆
	Sig. (2-tailed)	0.000		0.000	0.000	0.295	0.000	0.000	0.585	0.011
Handgrip	Pearson Correlation	.786⋆⋆	.615⋆⋆	1	.842⋆⋆	.641⋆⋆	.556⋆⋆	.805⋆⋆	.344⋆	-0.022
	Sig. (2-tailed)	0.000	0.000		0.000	0.000	0.000	0.000	0.040	0.903
Back-leg	Pearson Correlation	.760⋆⋆	.640⋆⋆	.842⋆⋆	1	.680⋆⋆	.667⋆⋆	.832⋆⋆	.399⋆	-0.067
	Sig. (2-tailed)	0.000	0.000	0.000		0.000	0.000	0.000	0.016	0.710
Push-ups	Pearson Correlation	0.264	0.179	.641⋆⋆	.680⋆⋆	1	.560⋆⋆	.676⋆⋆	.483⋆⋆	0.028
	Sig. (2-tailed)	0.120	0.295	0.000	0.000		0.000	0.000	0.003	0.877
SBJ	Pearson Correlation	.510⋆⋆	.625⋆⋆	.556⋆⋆	.660⋆⋆	.560⋆⋆	1	.716⋆⋆	0.174	-0.148
	Sig. (2-tailed)	0.001	0.000	0.000	0.000	0.000		0.000	0.311	0.412
MBT	Pearson Correlation	.749⋆⋆	.667⋆⋆	.805⋆⋆	.832⋆⋆	.676⋆⋆	.716⋆⋆	1	.380⋆	-0.201
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000		0.022	0.263
Sit-ups	Pearson Correlation	0.179	0.094	.344⋆	.399⋆	.483⋆⋆	0.174	.380⋆	1	0.125
	Sig. (2-tailed)	0.296	0.585	0.040	0.016	0.003	0.311	0.022		0.488
Squats	Pearson Correlation	-0.275	-.436⋆	-0.022	-0.067	0.028	-0.148	-0.201	0.125	1
	Sig. (2-tailed)	0.122	0.011	0.903	0.710	0.877	0.412	0.263	0.488	

Note. SBJ = Standing broad jump; MBT= Medicine ball throw; ⋆⋆. Correlation is significant at the 0.01 level (2-tailed); ⋆. Correlation is significant at the 0.05 level (2-tailed).

The correlation matrix presented reveals significant relationships between various measures of muscular fitness. The results of the statistical analysis are clearly presented in the following Table 2.

The correlation matrix presented reveals significant relationships between various measures of muscular fitness (table 2). Notably, there was a strong positive correlation between weight and handgrip ($r = .786$, $p < .01$), back-leg a MBT suggesting that heavier individuals tend to exhibit better results in these tests. This pattern is consistent with the positive correlation found between weight and back-leg ($r = .760$, $p < .01$), underlining the association between body mass and strength measures.

Height was significantly correlated with handgrip ($r = .0615$, $p < .01$), back-leg ($r = .640$, $p < .01$), SBJ ($r = .625$, $p < .01$), MBT ($r = .667$, $p < .01$), indicating that taller individuals might have an advantage in these strength tests. However, height was not significantly correlated with push-ups performance ($r = .179$, $p > .05$), indicating that push-up ability may not be influenced by a person's stature. The analysis also showed a negative correlation with squats ($r = -.436$, $p < .05$), indicating an inverse relationship between these two variables.

The standing broad jump (SBJ) was positively correlated with back-leg ($r = .660$, $p < .01$), which could indicate that overall explosive leg power contributes to back strength, or vice versa. The MBT showed strong positive correlations with handgrip ($r = .805$, $p < .01$), suggesting that handgrip strength is a good predictor of absolute strength. It was also significantly correlated with back-leg ($r = .832$, $p < .01$) and SBJ ($r = .716$, $p < .01$), reinforcing the association between these tests.

Interestingly, a negative correlation was found between weight and squats performance ($r = -.275$, $p > .05$), although it was not statistically significant, suggesting a potential trend that heavier individuals might perform fewer squats in this time frame.

In examining the correlation data, traditional tests displayed a varied range of associations among themselves. Handgrip showed positive correlations with both SBJ ($r = .556$, $p < .01$), push-ups ($r = .641$, $p < .01$) and sit-ups ($r = .344$, $p < .05$). This indicates that the muscular strength measured by handgrip is somewhat reflective of the abilities required for push-ups, sit-ups and explosive leg strength.

In contrast, the innovative tests presented significant correlations with both the traditional tests and among themselves. The back-leg correlated strongly with handgrip ($r = .842$, $p < .01$;), indicating a possible relationship between overall muscular strength and the specific back and leg muscles assessed in this test. Squats, however, showed not a significant relationship with back-leg (-.067, $p > .05$) and MBT (-.201, $p > .05$). The MBT demonstrated the highest correlation with back-leg dynamometry ($r = .832$, $p < .01$).

A comparison of the two sets of tests – traditional versus innovative – was conducted (Table 3). The analysis revealed a substantial positive correlation between the rankings of traditional and innovative tests ($r = 0.835$, $p < 0.01$), suggesting a strong concordance between them.

Tabulka 3./ Table 3.
Výsledky korelační analýzy pro tradiční testy a inovativní testy./ The results of the correlation analysis for traditional tests and innovative tests.

		Innovative tests	Traditional tests
Innovative tests	Pearson Correlation	1	.835⋆⋆
	Sig. (2-tailed)		.000
	N	36	36
Traditional tests	Pearson Correlation	.835⋆⋆	1
	Sig. (2-tailed)	.000	
	N	36	36

Note. ⋆⋆. Correlation is significant at the 0.01 level (2-tailed)

Discussion

The objective of this research was to compare traditional and innovative tests by examining their correlations and potential substitutability. Results indicate that in certain cases, tests demonstrated a strong relationship: handgrip with back-leg ($r = .842$), handgrip with MBT ($r = .805$) and SBJ with MBT ($r = .716$). However, in other instances, a weak relationship was reported, such as between

squats and sit-ups. Thus, only specific combinations of tests may serve as potential substitutes. The correlation between sets of test suggests that they could be interchangeable (r = .835), although it is important to consider that they were created for the purposes of this research.

The search for alternative muscular strength tests primarily pertains to individuals with health impairments or those with physical or mental limitations (McGough et al., 2019; Reychler et al., 2018). These are often simpler versions of tests that, while proven valid, are not suitable for the general population. For practical application among healthy adults, it is crucial to have a range of field tests capable of objectively evaluating the level of selected strength levels. This allows for the inclusion of more demanding tests. An example is the two-minute squat test, which is both physically and mentally demanding because of the intense muscle burn experienced during the exercise.

Dynamometry is a valid and reliable method for measuring muscular fitness, but it can yield misleading results regarding health. Cooper et al. (2022) discovered a positive relationship between BMI and handgrip strength. This relationship suggests that obese individuals may exhibit strong results in absolute muscular strength. Nonetheless, these individuals are at risk of sarcopenic obesity later in life and fall into a risk category for other lifestyle-related diseases. Our measurements indicate that the same relationship applies to the back-leg test. The relationship between anthropometry, BMI, and dynamometry is complex and must be contextualized for specific groups (Murphy et al., 2014). Furthermore, it is important to assess body fat distribution, as individuals with a larger waist circumference and high BMI typically show lower handgrip strength levels (Keevil et al., 2015).

The observed strong correlation between handgrip and back-leg dynamometry in our study likely reflects underlying physiological and biomechanical commonalities. Handgrip strength is not merely a function of hand and forearm muscles; it also engages the upper body's synergistic muscular actions (Vaishya et al., 2024). Similarly, back-leg dynamometry requires the activation of the posterior chain muscles, which include the lower back, gluteus, and hamstrings-muscles that also play a role in maintaining an effective grip (Martín-Fuentes et al., 2020). This suggests that individuals who exhibit greater handgrip strength may inherently possess a well-developed posterior muscular chain, contributing to stronger performance in back-leg dynamometry.

Muscular endurance testing was conducted using traditional tests such as push-ups and sit-ups. It was observed that push-ups were challenging for some individuals (1-5 repetitions), which implies that the test may assess maximum strength rather than endurance. This could be related to the moderate correlation between these tests (r = .483). Squats test was used as an innovative alternative, yet it demonstrated only a weak correlation with traditional tests (r = .125, .028 respectively). It is evident that tests targeting the upper and lower body reveal differences and cannot be directly substituted for one another. However, lower body endurance could be more closely related to health parameters (Alcazar et al., 2018), suggesting the importance of including such tests in evaluations.

Explosive strength tests are often included in the evaluation of muscular fitness. The tests we selected, the MBT and the SBJ, demonstrated a strong correlation (r = .716), suggesting they could be used interchangeably. However, it is debatable whether this type of strength is suitable for testing across all age groups or whether more universally applicable methods should be considered. The SBJ, for instance, imposes a relatively high load on the knee joints and spine (Eagles et al., 2016; Schäfer et al., 2023), making it a good option for younger individuals but perhaps unsuitable for older adults. Thus, the MBT represents a less strenuous alternative that also showed a strong correlation with dynamometry, indicating its efficacy in assessing absolute strength.

The observed correlations among tests likely arise from underlying physiological and biomechanical factors. For instance, the strong relationship between handgrip and back-leg dynamometry may be due to shared engagement of the posterior chain muscles, including the lower back, gluteus, and hamstrings, which contribute to strength in both upper and lower body assessments. This suggests that individuals with higher handgrip strength often possess a more developed posterior chain, supporting better back-leg performance. Similarly, the moderate correlation between handgrip and the MBT may stem from the coordinated upper body power required in both tests, though achieved through different muscular pathways. In contrast, the weak correlation between squats and sit-ups likely reflects the distinct muscle groups and endurance types each test engages; squats emphasize lower body endurance, more closely tied to health factors like balance and mobility, while sit-ups primarily test core endurance. The strong relationship observed between MBT and SBJ suggests these tests share a demand for

explosive lower body power, though the SBJ places more strain on the knees and spine, making it potentially more suitable for younger individuals, while MBT serves as a less strenuous alternative for assessing upper body power. Understanding these physiological relationships helps clarify why certain tests correlate and supports more targeted selection based on fitness attributes and population needs.

Once again, it is confirmed that for a comprehensive assessment of muscular fitness, it is necessary to use multiple tests targeting different body parts and measuring various parameters such as muscular endurance, absolute strength, or explosive strength (Schlegel et al., 2023). A significant relationship between the individual traditional and innovative tests was only evidenced in certain cases. It is not yet possible to definitively determine which tests provide the best diagnostic value for health in a healthy adult population, hence they must be carefully selected, combined, and sensitively interpreted (Bohannon, 2019).

In line with the stated arguments, it can be asserted that traditional muscle fitness tests have limited interpretive value, and their interrelationships do not always accurately reflect an individual's overall fitness. Therefore, it is essential to consider the use of alternative testing methods that better align with current scientific findings and reflect shifts in the understanding of muscle fitness and its significance in overall physical conditioning. The perspective on muscle fitness and approaches to its assessment are gradually evolving. For instance, the commonly used sit-up test, often regarded as a standard, could be replaced by more suitable tests that more accurately evaluate muscular strength and functional capacity.

The search for new testing methods is also translating into everyday practice. Teachers and coaches often find themselves in situations where they must select the most appropriate test tailored to a specific individual or group. Various factors, such as age, anthropometry, health limitations, and movement preferences, can significantly influence test selection. For this reason, it is essential to have a broader range of tests available, allowing for adjustments that better reflect these individual characteristics.

Based on the findings from this study, it would be useful to conduct a longitudinal study to track the evolution of test correlations over time, particularly in the context of individuals' regular training. Such a study could reveal the effect of sustained exercise on parameters of strength and endurance captured by both traditional and innovative tests. In addition, a larger study with a more diverse set of participants would help validate our initial findings and ensure that the observed correlations are robust across different demographic groups and are not simply due to the size or composition of our sample.

As a pilot study, this research provides valuable preliminary data, yet it comes with inherent limitations that must be acknowledged. The sample size, while sufficient for exploratory purposes, is relatively small, which may limit the generalizability of the findings to larger and more diverse populations. Additionally, as the scope of a pilot study is inherently exploratory, the results primarily serve to inform and refine hypotheses, methods, and procedures for subsequent, more comprehensive studies. The selection of tests, though varied, may not encompass all aspects of muscular fitness, and the division into traditional and innovative categories, while conceptually useful, may oversimplify the complexities of physical fitness assessment. From a practical application perspective, we must acknowledge that we do not have strong, robust data, and therefore we cannot yet fully recommend the use of innovative tests

Conclusion

This pilot study highlights the crucial role of muscular fitness in overall health, which justifies its rigorous evaluation. Although the innovative tests explored show some degree of correlation with traditional tests, suggesting that they may serve as a partial alternative, establishing a direct replacement remains challenging. The development of an innovative test battery presents a compelling argument that, in certain scenarios, this suite could replace traditional tests used for healthy adult populations. However, the conclusions drawn from this research apply specifically to a healthy adult population and emphasize that finding an exact equivalent in fitness assessment is difficult and requires further validation. It is important to consider that this is a pilot study, and further research is needed to confirm the conclusions. Until then, it would be advisable to use the innovative tests with caution.

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Table 1
Money Towards Cancer Research in 2008

Type	National Cancer Institute	American Cancer Society
Lung	$247.6 million	$20.4 million
Breast	$572.6 million	$35.5 million
Prostate	$285.4 million	$15.8 million
Colorectal	$273.7 million	$26 million
Melanoma	$110.8 million	$10.3 million

Note. Adapted from "Cancer Research: Where the Funding Goes," by Everyday Health, updated in 2010, Retrieved from https://www.everydayhealth.com/cancer/cancer-research-where-funding goes.aspx.

Grafy, obrázky apod. jsou zpravidla samostatnými listy zpracovanými v kvalitě, která odpovídá požadavkům přímé předlohy pro tisk (černobílé obrázky a grafy a tomu odpovídající popisky, rozlišení min. 300 dpi). Rozměry musí respektovat vymezenou stránku. Použité názvy a popisy musí být uvedené rovněž dvojjazyčně, tj. česky, resp. slovensky a anglicky. Doplňující informace se uvádějí pod obrázek či graf. Obrázky a grafy mají souhrnný charakter a nerámují se. Grafy a obrázky mohou být v barevném provedení.

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Autoři, jejichž příspěvek má vazbu na projekt *grantové agentury* a je součástí dílčí nebo závěrečné *zprávy výzkumného projektu* musí toto uvést. Např.: Empirická data byla získána v rámci řešení grantového projektu např. GAČR (název a číslo).

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Scientific Journal for Kinanthropology is mainly a place for publishing reports of empirical studies, review articles, or theoretical articles. Articles are published in Czech, Slovak, and/or English language. The author (senior author) is responsible for special and formal part of the article. All texts are subject to review process and assessed by at least two expert referees. The review procedure is authorless. Board of editors decide about article´s publishing having regard to scientific importance and review process.

Most journal articles published in kinanthropology are reports of empirical studies, and therefore the next section emphasizes their preparation.

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(b) *Author´s name and affiliation*
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• the problem under investigation, in one sentence if possible;
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• the findings, including statistical significant levels, and
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