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SWIM START EFFECTIVENESS AND LOWER LIMB POWER OF YOUNG MALE AND FEMALE SWIMMERS

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A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
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Abstract:

Introduction. The aim of this study was to determine whether the mechanical power of the lower limbs influences swim start effectiveness in young swimmers.

Material and methods. 32 swimmers aged 15-16 performed the CMJ (counter-movement jump) and SJ (squat jump). The following were measured: jump height (H), maximal speed (v_{MAX}), maximal and average power in absolute (P and P_A, respectively) and relative terms (P_{REL} and P_{AREL}). Registration of the starting jump to freestyle with the measurement of the time to cover the first 10-m distance (t_{10}) was registered. The following were determined: length and time of flight (L_f, t_f), height of the hip joints at the time of the start signal (H_h), angle in the hip joints at the moment of loss of contact with the block (A_T) and the moment of emerging fingers in water (A_E), as well as angle of water attack (A_A). The significance of differences between the mean values recorded in the group of boys and girls was assessed, while correlations between variables were described.

Results. In the boys' group, only H_h correlated negatively with t_{10} (r=-0.57). There were significant differences in the level of all variables recorded for girls and boys during the CMJ and SJ. At the same time, none of the indicators characterizing the CMJ were correlated with t_{10}. In the boys' group, significant correlations were found between t_{10} and H, v_{MAX}, P, P_{REL} and P_A in the SJ ($-0.51 \le r \le -0.72$).

Conclusions. In boys, the time to cover the first 10 m was shorter, while the values for time and flight length as well as the height of the hips on the starting block and the value of the angle in the hip joints during push-off were higher. One of the reasons for these disproportions may be differences between gender in the power of the lower limbs and techniques for performing the starting jump. The relationship between the on-land trials testing mechanical power of the lower limbs and the time of the swim start is stronger in boys. The CMJ seems to be of little usefulness in predicting the effectiveness of a swim start.

Introduction:

Swimming races take place under circumstances unheard of in other sports. This uniqueness results directly from the properties of the environment in which such a competition takes place. In order to fulfil these conditions, the swimmer must overcome the resistance placed on him/her by water, and also emerge his/her face to take a breath. Additionally, apart from the breaststroke, the majority of the propulsion is achieved thanks to appropriate upper limb movements. For these reasons, swimming is sometimes classified as a "technical" sport in which a high level of performance is essential for achieving success. However, perfect mastery of swimming technique is not a sufficient guarantee of sports success. In addition to cyclical motions, acyclic movements (e.g., starting jumps, turns) are also significant elements of competitions at the pool. It is known that a swimmer poorly performing these elements of the competition will not be able to achieve high results.

Assuming the stance of Blanksby et al. [1] that swim starts cover the first 10 m of a race, in 50-m competitions, this phase constitutes 20% of the total distance. Due to the fact that the ranking of places on the podium at the most important swimming competitions is often determined by differences of 0.2 s [2], the start may determine whether a competitor wins or loses. Therefore, a flawless start of the race is key to success, especially in the case of short distances (50-100 m).

The time of the swim start consists of the time on the starting block, flight and entry into the water, gliding, swimming under water and swimming the full style to a specific point (usually 10 or 15 m from the starting line) [3]. The term "starting jump" is often used to describe the first two phases of a swim start when the swimmer's body is not in contact with water. The starting jump (from the sound signal to the fingers' contact with water) lasts less than 2 seconds, but has significant impact on the quality of consecutive movements [3, 4]. In a relatively short time, the swimmer must correctly perform multiple, successive sequences , which causes the reliable assessment of starting jump quality to be problematic, even for experienced coaches. The use of modern technologies, such as high-speed cameras, has significantly increased the reliability of swim start assessment by coaches. Properly recorded video material can also be used for more complex kinematic analysis, which usually determines quantitative indicators describing the jump, such as time or flight length [4]. The values of these indicators, properly interpreted, can help diagnose the weaknesses and strengths of the starting jump, which, in turn, can be used in technical correction of the swimmers.

Due to physiological differences between sexes, research regarding the starting jump usually include only male or female groups [5]. This is probably why relatively little is said about gender-related differences in the performance of swim starts. In the few available works comparing swim starts in the aspect of differences according to gender, it was found that, in men, the time of start-reaction is shorter and the push-off strength is higher, while the jump itself is characterized by longer flight length [6-8]. All this causes men to achieve shorter average start times than women [8]. Thanopoulos et al. [6] believe that this is the effect of gender-related differences in the power of the lower limbs. These, in turn, are the resultant of structural and functional differences of the muscles of men and women described, among others, by Trzaskoma [9].

The data obtained by several authors [4, 7, 10] prove that the effectiveness of the starting jump depends not only on gender, but also on other individual factors such as somatic build, sports level or the age of the subjects. Undoubtedly, the last of these factors is connected to competitive experience, the level of acquired skills and training. In light of this information, it seems obvious that the performance of each element of the swimming race by younger athletes significantly differs from the results of adult competitors. The swim start is no exception [4]. There are indications that certain phenomena occurring among children and youth practicing sport may not be visible in groups of experienced competitors. This seems to be confirmed in the research by, among others, Strzała et al. [11], who found a relationship between anaerobic abilities and the results of short-distance swimming among 12-14-year-olds, and at the same time, did not show such relationships in older age groups. Therefore, comparing the results of studies among children and adolescents with the results obtained for adults, has its limitations. This does not mean, however, that research should not be undertaken in younger training groups. As shown by Figueiredo et al. [12], research involving children and youth can serve to set more realistic expectations and goals for these training groups.

It is known that in addition to training sessions in the water, athletes also undergo on-land training [13, 14]. The structure of the discussed training is mainly subordinated to the distance in which the swimmer specializes [15]. In the case of short-distance athletes, on-land strength and power training should have a significant share in this part of the training process [14]. Such a conclusion is justified by research the of Morouco et al. [16]. They found that there is a correlation between the results of on-land anaerobic power testing and the results in swimming short distances. It seems likely that adequately high anaerobic power is desirable in such activities as the swimming start described earlier.

Effective push-off from the starting block is not possible without explicit involvement, among others, of the gluteal, thigh and shank muscle groups [17]. It is essential that the on-land tests used in assessing the relationship between anaerobic power and the swim start comprehensively involve the lower limb muscles. Such requirements are met by tests in the form of vertical jumps [9, 14] of the following types: CMJ (countermovement jump), SJ (squat jump), performed with or without arm swing [18, 19]. This is probably why many authors undertook research determining the relationship between the effectiveness of the starting jump and the results of vertical jumps [2, 10, 13, 19, 20]. To determine such relationships, usually more than one on-land test is used [14, 18], but there are also descriptions of the correlation of the swim start with different indicators of one type of the tests [19]. The methodological inconsistency of the research indicated here raises the necessity to unequivocally identify land trials with the highest predictive values for the time of the swim start.

From the research carried out so far, it is not clear whether power training of the lower limbs on land would translate into shorter swim start time. West et al., Garcia-Ramos et al. and Beretić et al. [13, 19, 20] noted the relationship between the power of the lower limbs measured on land and the effectiveness of the jump in both adult male competitors [13, 20] and 15-year-old girls [19]. In turn, Benjanuvatra along with his research team [10] and Breed and Young [18] showed that on-land training aimed at increasing the power of the lower limbs improved the results of on-land trials, but did not translate into a shorter start time. It is worth noting, however, that research in this area included only homogeneous groups in terms of gender. So far, no research has been conducted that would give an answer as to in which sex the relationship between lower limb power and swim start is greater.

The main motive for undertaking this research was the already signalled attention to the significant impact of the swim start on the final time achieved for a short distance. Another contribution was the lack of unambiguous reports on the relationships between the power of the lower limbs and the effectiveness of the swim start. The effects of the research were also influenced by the negligible amount of literature that affected this issue from a dimorphic perspective.

The objective goal of research was to determine whether the mechanical power of the lower limbs influences the effectiveness of the swim start among young swimmers. This issue was solved using comparative analysis of kinematic starting jump indicators and variables characterizing the mechanical power recorded in the representatives of both sexes during jumps on the dynamographic platform. The next step in the undertaken research was to seek interdependencies between variables describing the implementation of both mentioned motor tasks. Statistical analysis of the results was to form the basis for their practical use in coaching work with young swimmers.

Achieving the above objectives was to facilitate finding the answers to the following research questions:

1. Is there a relationship between lower limb power and swim start time?
2. Is the strength of correlations between mechanical power of the lower limbs and the indicators of the swim start the same for both genders?
3. Which variables characterizing the vertical jump are most strongly correlated with swim start time?
4. Can the results of the conducted research be used in training young swimmers?
5. What are the quantitative differences in variables describing the swim start in boys and girls?

Material and methods:

The study was carried out at the 6-lane, 25-m long, indoor swimming pool of the Sports Championship School in Krakow. The study group comprised 32 volunteers (17 girls, 15 boys) from two different classes at the above-mentioned school. Characteristics of the group are included in Tab. 1. The sports level of each subject was determined on the basis of his/her personal bests converted into FINA classification points according to the following formula: $P = 1000 * (B / T)^3$, where B – is the world record for a given competition and T – is the best time achieved by the swimmer. The necessary data were downloaded from the following website: https://www.swimrankings.net/.

Both the subjects and their legal guardians were acquainted with the procedure of carrying out measurements and agreed to participation in the study. All swimmers were informed about the possibility to resign from measurements at any stage, however, none of the respondents exercised this right.

Tab. 1. Characteristics of the studied group (F – females, M – males).

	Number	Age (years)	Body height (cm)	Body mass (kg)	FINA points
F	17	15.3	166.79	60.54	556
M	15	15.7	178.89	70.30	568

According to previously developed methodological assumptions, the tests consisted of two consecutive parts. In the first one, swimmers performed vertical jumps on the dynamographic platform, while in the second, they performed jumps to freestyle. Such a sequence of attempts was done for safety reasons. In this way, the jumps on the platform were performed when the swimmers were dry, thanks to which the measuring equipment was not exposed to water. A different protocol and a different sequence of attempts could promote uncontrolled slipping during the jump, which would significantly increase the risk of injury. The aforementioned suboptimal measurement conditions could also affect the level of motivation of swimmers during the jump, which would translate into worse results. From the point of view of the objectives of research, the proposed methodology turned out to be correct.

Before beginning the measurements, the subjects underwent a typical 10-minute warm-up on land, different than the typical larger amount of lower limb exercises. After the warm-up and demonstration of the test, the subjects performed two jumps on a dynamographic platform. It was set at a sufficient distance from the pool so as not to get wet. The platform operator was the same for each jump and was appropriately trained to perform such measurements.

Each trial was preceded by a demonstration and appropriate instruction. All subjects wore swim suits, without shoes. The subjects were informed about the need to perform each jump in a way that would allow the body to be lifted to the maximum possible height. The following were performed consecutively:

1. Counter Movement Jump (CMJ) – course of trial as in Breed and Young [18] – the subjects began in standing position with arms along their body. After the signal, a maximal jump with arm swing was performed (Fig. 1).
2. Squat Jump (SJ) – course of trial as in Garcia Ramos et al. [19] – through flexion of the lower limbs, the subjects assumed a squatted position (angles in the knee and hip joints approx. 90^{o}) with hands placed on the hips. From such a set initial position, after the signal, the vertical jump was performed without arm swing (Fig. 2).

Fig. 2. SJ: 1. Starting position 2. Beginning of flight phase 3. Highest position during flight 4. Completion of flight

Fig. 1. CMJ: Starting position 2. Lowest position during swing phase 3. Beginning of flight phase 4. Highest position of the body during flight phase 5. Completion of flight 6. Position during amortization phase.

Trials of each type (CMJ, SJ) were performed in the same order. This provided each person with a similar amount of time for several minutes of passive rest between the vertical jumps.

Connecting the dynamographic platform to the computer made it possible to register the ground reaction force using the "JBA" Zb. STANIAK MVJ v4.0 programme. It was also in this programme that data were saved, archived and analysed. For the purpose of this work, the following variables were determined for each jump:

– vertical displacement of the centre of mass relative to the highest point of flight [m] – H
– maximal speed [m/s] – v_{MAX}
– maximal power [W] – P
– maximal relative power [m/s] – v_{MAX}
– average power [W] – P_A
– average relative power [W/kg] – P_{AREL}

After performing the tests on the dynamographic platform, preparations for recording the starting jump video were initiated. On the subjects' bodies, the following anatomical points were marked with a waterproof pen: the fifth finger of the left hand, the inner ankle of the left lower limb and the medial ankle of the right lower limb. The course of the transverse axis of the hip joint on the left side of the body was also marked. All markings were performed by the same trained person with appropriate anatomical knowledge. Each marker placed on the skin was fully visible from a distance of at least approx. 6 m. After marking the characteristic points of the body, the subjects proceeded to a warm-up in water conducted by the coach. At the end of the warm-up, each swimmer performed a series of several swimming jumps.

After the warm-up, during the break lasting about 10 minutes, the subjects were acquainted with the further measurement procedure. They were informed that the starting jump to freestyle should be performed in accordance with FINA regulations, the same way as during sports races at swimming competitions, that is in the shortest possible time; the start signal was the sound of a whistle.

Each subject chose the technique for performing the swim start according to the one used at competitions. The athletes could do a “grab start” (before the start signal both feet are on the front edge of the block) or “track start” (from a forward lunge position) (Fig. 3). All subjects chose the second type of jump.

The starting jumps were recorded using the Casio Exilim EX-FH25 (frequency: 120 frames/s, shutter: 1/200 s, the number of apertures: 2.8, the size of a single frame: 640x480 pixels). The distance of the apparatus from the lane where the subjects performed the jump was approx. 5 m. The device was set perpendicular to the direction of movement of the subjects so as to record their entire above-water movement. After performing video registration of the jumps, a calibration frame was placed on the measuring lane to determine the actual movements of the swimmers.

Simultaneously, with video recording, using an electronic stopwatch, the time needed to cover the first 10 m was measured (t_{10}). The stopwatch was turned on at the time of the start signal, and turned off when the middle of the athlete’s head passed the 10-m line from the starting wall. Each of the swimmers performed two starting attempts, with 3 minutes of passive rest between them.

After video registration of the jumps, a rectangular calibration frame with the dimensions of 2.04 m x 1.02 m (width x height) was placed on the measuring lane, which was also recorded. This makes it possible to determine the actual movements of the swimmers in the subsequent processing of the video material.

The analysis of recording began with the selection of the collected footage. For further digital processing, the jump recording after which the subject obtained the shortest start time to cover the first 10-m was chosen. This video was subjected to kinematic analysis using the SkillSpector programme. With the 4-point mathematical model developed by the software designers, the course of movement of points marked on the body of the subjects was reconstructed. Graphs of the changes in the position of these points were also generated using the SkillSpector programme. Thanks to that, the following kinematic variables describing the starting jump were determined:

– flight length [m] – L_f
– flight time [s] – t_f
– height of hip joints on the block at the time of the start signal [m] – H_h
– angle in the hip joints at the moment of losing contact with the block [deg] – A_T
– angle in the hip joints when the fingers submerged in water [deg] – A_E
– water attack angle – A_A [deg] – the angle between the surface of the water and the body when the fingers submerge in water.

Fig. 3. Starting jump. From left to right: initial position on the block loss of contact with the block (beginning of the flight phase), finger contact with water (completion of flight).

Statistical analysis of the results was performed using the Statistica programme (v. 11). After the division of the research material according to gender, descriptive characteristics of all variables were given. Next, the significance of differences between the mean values of these variables recorded in the groups of boys and girls (tests for independent samples) was assessed. Finally, the strength and direction of correlational relationships between particular variables were determined in both groups (Pearson’ *r*). The used statistical tools were adequate to achieve the intended research objectives, which is confirmed by the literature in this field [13, 20].

Results:

The results of the conducted research indicate that the average time to cover the first 10-m distance (t_{10}) was 4.49 s in boys and was significantly shorter ($p<0.001$) than girls (5.02 s). Analysis of Tab. 2 proves that the other indicators characterizing the technique of performing the starting jump by girls and boys significantly differed. In the case of almost all the described variables, higher values were recorded in the group of males. At the same time, only in flight length (L_f), hip height on the block during the start signal (H_h) and the angle of the hip joints at the moment of loss of contact with the block (A_T) were the differences statistically significant ($p<0.05$). These differences, in percentage terms ranging from approx. 6% (H_h and A_T) to approx. 12% (L_f), are presented in Fig. 4.

In Tab. 3, the results of correlation analysis aimed at searching for dependencies between kinematic variables of the push-off (t_{10}) are provided. It turned out that only in the group of boys was the value of t_{10} significantly correlated with the height of the hips (H_h) on the block at the time of the start signal. The strength of this relationship was described by Pearson's correlation coefficient: $r = -0.61$. The remaining variables of the starting jump in the group of boys did not show significant relationships with t_{10}. The above-mentioned table also indicates that in the group of girls, none of the starting jump indicators generate significant correlational relationships with the time to cover

Tab. 2. Variables characterizing starting jump taking differences in values noted in the group of girls (F) and boys (M) into consideration.

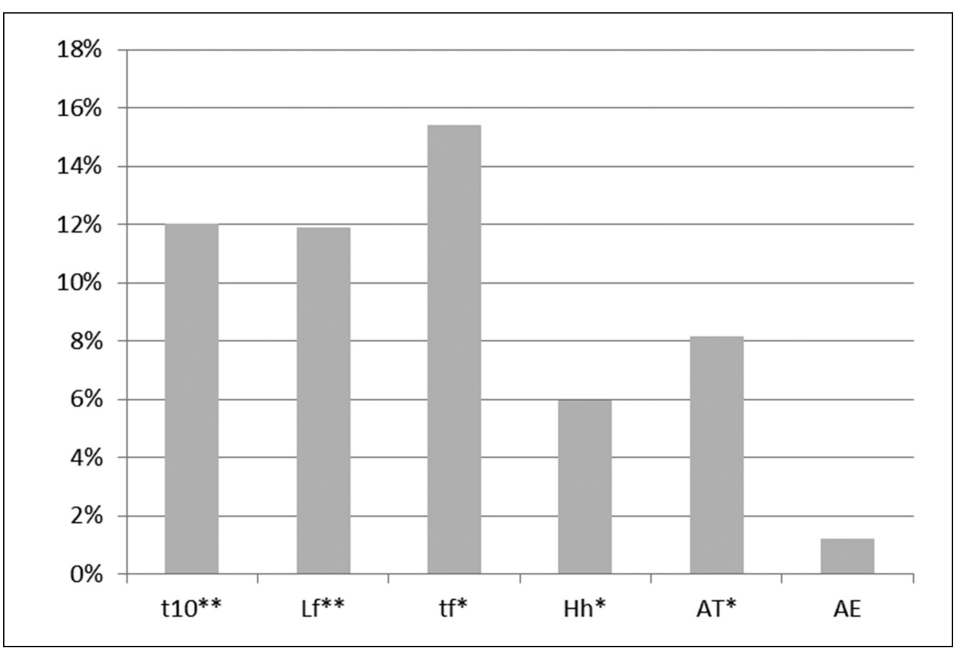
	F	M
	$\bar{x}\pm SD$	$\bar{x}\pm SD$
t_{10} [s]**	5.02 ± 0.25	4.49 ± 0.29
L_f [m]**	2.78 ± 0.14	3.11 ± 0.21
t_f [s]	0.26 ± 0.07	0.30 ± 0.07
H_h [m]*	1.18 ± 0.05	1.25 ± 0.06
A_T [deg]*	135 ± 12	146 ± 12
A_E [deg]	166 ± 18	168 ± 16
A_A [deg]	39 ± 7	39 ± 9

*$p<0.05$
**$p<0.001$

Tab. 3. Pearson's correlation coefficient values between the time to cover 10 m (t_{10}) and kinematic variables of the swim start.

	F	M
L_f [m]	-0.11	-0.19
t_f [s]	0.37	0.22
H_h [m]	-0.30	-0.61*
A_T [deg]	-0.18	-0.19
A_E [deg]	0.15	-0.12
A_A [deg]	0.09	-0.10

*$p<0.05$



*, ** – statistically significant differences for $p<0.05$ and $p<0.001$, respectively.

Fig. 4. Differences between genders of variables characterizing starting jump in percentages among boys and girls.

the 10-m distance (t_{10}). At the same time, it is worth noting the emerging tendency of negative relationship creation ($r < 0$) between kinematic starting jump indicators with t_{10}, especially pronounced in the group of boys .

All indicators characterizing CMJs were higher in boys (Tab. 4). Additionally, all differences between the mean values recorded in the groups of swimmers of both sexes were statistically significant. In the range of maximal (P) and average power (P_A), the differences were the highest and amounted to approx. 50%. The same indicators, but in relative terms (P_{REL}, P_{AREL}), differed from 20% to 30% in girls and boys. The smallest variation in values among the male and female groups was found in the range of maximal jump speed (v_{MAX}). The mean value of this variable in boys was 2.57 m/s and was just a bit more than 10% higher than in girls (2.31 m/s). All described differences between genders are presented in Fig. 5 .

The conducted research proved that all variables determined on the basis of the SJ also showed significant differences depending on gender. This observation is illustrated by the numerical data in Tab. 5 and their graphic representation in Fig. 6. As can be seen, all kinematic and dynamic indicators of the SJ vertical jump type were higher in the boys' group. All differences observed between the groups of swimmers were statistically significant. These differences ranged from less than 20% (v_{MAX}) to over 70% (PA).

The conducted correlational analysis did not reveal any significant relationships between t_{10} and the results of the CMJ trial (Tab. 6). This observation concerned both the group of boys as well as girls. Admittedly, in

Tab. 4. Statistical characteristics of the CMJ results in the groups of studied swimmers (both males and females).

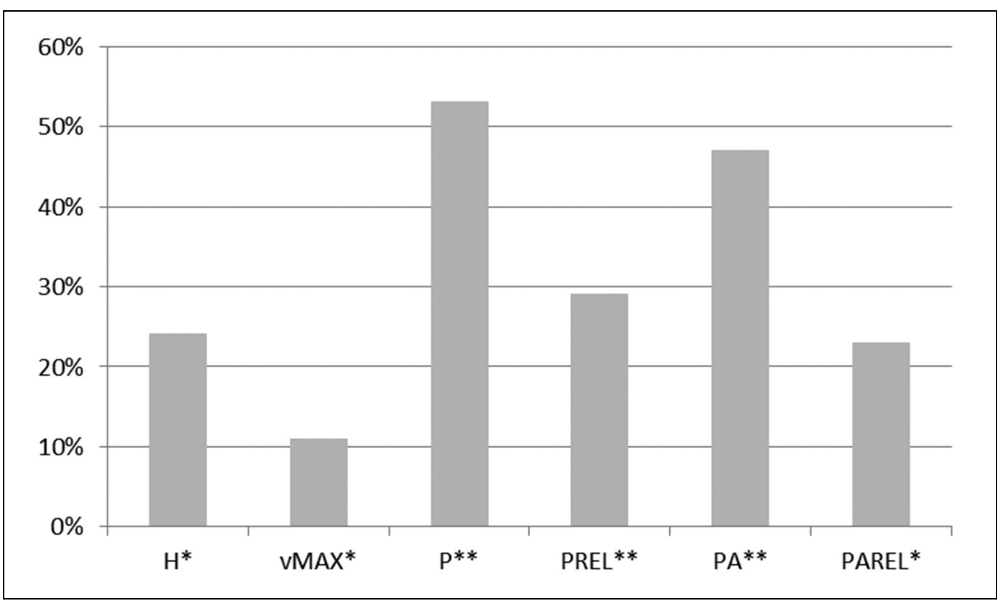
	F	M
	$\bar{x}\pm SD$	$\bar{x}\pm SD$
H [m]*	0.29 ± 0.04	0.36 ± 0.07
vMAX [m/s]*	2.31 ± 0.19	2.57 ± 0.25
P [W]**	1271 ± 224	1948 ± 334
PREL [W/kg]**	20.59 ± 4.15	26.65 ± 3.14
PA [W]**	661 ± 172	969 ± 241
PAREL [W/kg]*	10.73 ± 3.11	13.25 ± 2.80

*$p<0.05$
**$p<0.001$

Tab. 5. Statistical characteristics of the SJ results in the groups of studied swimmers (both males and females).

	F	M
	$\bar{x}\pm SD$	$\bar{x}\pm SD$
H [m]**	0.26 ± 0.05	0.33 ± 0.05
vMAX [m/s]**	2.10 ± 0.24	2.46 ± 0.19
P [W]**	1058 ± 217	1740 ± 338
PREL [W/kg]**	17.08 ± 3.57	23.88±3.68
PA [W]**	487 ± 130	851 ± 193
PAREL [W/kg]**	8.45 ± 2.81	12.09 ± 2.63

*$p<0.05$
**$p<0.001$



*, ** – statistically significant differences for $p<0.05$ and $p<0.001$, respectively.

Fig. 5. Differences in variables noted in swimming groups during the CMJ in percentages.

Tab. 6. Pearson's correlation coefficient values between the time of swim start and CMJ results.

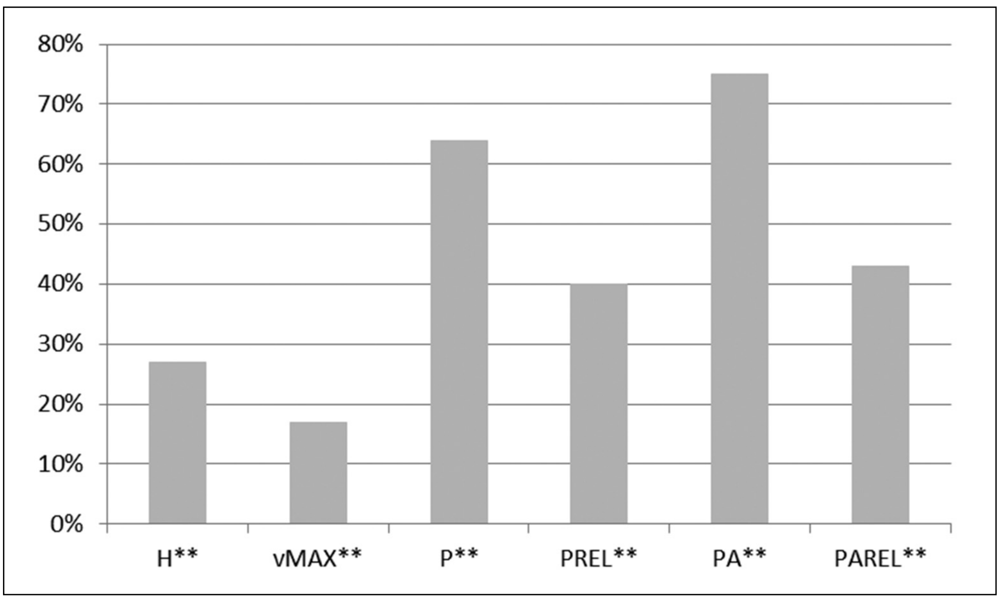
	F	M
H [m]	0.03	-0.24
v_{MAX} [m/s]	0.06	-0.26
P [W]	-0.37	-0.33
P_{REL} [W/kg]	-0.17	-0.15
P_A [W]	-0.41	-0.11
P_{AREL} [W/kg]	-0.28	0.03

*$p<0.05$

Tab. 7. Pearson's correlation coefficient values between the time of swim start and SJ results.

	F	*M*
H [m]	0.24	-0.71*
v_{MAX} [m/s]	-0.06	-0.72*
P [W]	-0.13	-0.61*
P_{REL} [W/kg]	0.03	-0.51*
P_A [W]	0.31	-0.68*
P_{AREL} [W/kg]	0.17	-0.33

*$p<0.05$



*, ** – statistically significant differences for $p<0.05$ and $p<0.001$, respectively.

Fig. 6. Differences in variables noted in swimming groups during SJ in percentages.

individual cases among girls, *r*-values were recorded at an average level (e.g. $r=-0.41$ for P_A), but even these relationships turned out to be non-significant .

The image of the effects of searching for correlational relationships between t_{10} and the results of the SJ vertical jumps type was different than in the case of the CMJ. The results of this type of analysis are presented in Tab. 7. On their basis, it can be concluded that such correlations were stronger in boys. In this group, almost all relationships were statistically significant. It should also be emphasized that the described correlations were negative. This means that the high level of kinematic and dynamic vertical jump indicators of the SJ were connected with the time to cover the 10-m distance (t_{10}). The correlations with maximal speed ($r=-0.72$), jump height ($r=-0.71$) and average power ($r=-0.68$) turned out to be of greatest strength. Slightly weaker correlations were found between t_{10} and maximal as well as relative power. *R* values ranged from -0.51 to -0.61).

Discussion

The results of the present study show that boys performed the swim start faster than the girls, which is evidenced in the achieved time to cover the first 10-m distance (t_{10}). In this group, a longer length of flight after push-off from the block following the start signal (L_f) was also noted. Such an observation is not surprising, because similar ones were also noted in the available literature [6, 7]. Of course, it cannot be said that there is total similarity to the differences distinguished in other publications, probably resulting from the different selection of groups.

Analysis of the results of the authors' research also allowed to see other differences between sexes in the technique of performing the starting jump. One of them is the position of the hips on the block at the time of the start signal (H_h). The value of this variable was higher in boys, which was probably due to the larger size of the male body. Longer limb length in males is why they are able to set their hips in a higher position on the starting block than females.

The discussed high position of the hips on the block may, in a favourable manner, affect flight length. According to Alpetkin [7], the height of the centre of mass at the moment of leaving the starting block affects the length of the flight. A low hip position before the start signal raises the need to lift the hips via properly performed push-off. Unfortunately, this usually results in an increase in the vertical component of the surface's reaction force. As a consequence, the horizontal component of the velocity vector, affecting the effectiveness of the swim start, decreases [5]. As it has been demonstrated in earlier studies, it is the horizontal speed in flight that, to a large extent, determines start time [22]. This is why it should be recommended that the swimmers assume a position with the hips raised as high as possible after the "Take your marks" command. In the case of athletes with reduced agility, it may be difficult for them to assume such a position on the starting block, and therefore, they should devote sufficient time to training this element, also in relation to the lower limbs.

The value of the angle in the hip joints at the end of push-off (A_T) noted in the boys indicated significantly lower flexion of the lower limb in this joint (over 10 degrees) compared to girls. At the same time, the angle at the moment of immersion of fingers in water (A_E) was similar in both sexes. The values noted among boys and girls for angle of water attack (A_A) also turned out to be similar. This seems to indicate that, in boys, during push off, the extension movement was characterized by a greater range than in girls. Such disparities in genders probably stem from differences in reaction time and the motor-related consequences of the given differentiation. As it is known, men are characterized by an average shorter reaction time than women [23, 24]. In the case of the starting jump, this is facilitated by the earlier performance of trunk lift. It is perhaps thanks to this that the athlete can devote more time to extension of the lower limbs in the hip joints, which in turn, allows an increase in the range of motion regarding the described joints, positively affecting flight length. Such reasoning, however, did not find full support in the results of this study. It turned out that of all starting jump variables, only the height of the hips on the block at the time of the start signal (H_h) significantly correlated with t_{10} (r=-0.61). In addition, this relationship was only demonstrated in boys. In girls, no relationship was found between kinematic jump indices and the time of covering the first 10-m distance. Most surprising seemed to be the fact that the flight length did not affect the start time. It is known that the density of air is less than the density of water, and therefore, the longer the competitor is in flight, the less distance s/he has to overcome in a medium with greater resistance. For these reasons, one should expect significant correlational relationships between the discussed variables. One of the possible reasons for the lack of such dependencies can be found in the results of research by Tor et al. [22] carried out among world-class swimmers. The authors stated that flight time and the distance overcome in the air are not the main factors influencing the time to cover the first 10-m distance. In their opinion, the horizontal velocity at the moment of push-off is a much more important indicator [22]. The combination of appropriate positioning on the starting block and a push-off generating high horizontal speed can be an effective strategy to improve push-off time. However, it should be noted that in the authors' research, the athletes represented a slightly lower level of sports than those participating in the measurements by Tor et al. [22]. Therefore, it is impossible to rule out the influence of the subjects' sports level on the discussed results. Consequently, to finally determine the variables affecting the time of swim start, further measurements should also take the horizontal velocity at the time of loss of contact with the starting block into account.

Previous studies [25, 26] prove that the strength and mechanical power measured by on-land tests have impact on sport results when swimming short distances. The question is whether there is a connection between the results in the vertical jump and the time of swim start. Benjanuvatra et al. [10] did not find such a correlation. In turn, Cossor et al., West et al. and Garcia-Ramos et al. [2, 13, 19] proved that the vertical jump (with or without swing) is related to the time of the swim start. However, as noted in the introduction, research in this area so far has only included groups of men [13] or women [10, 19], without comparing the results of both groups with each other. So far, research on this subject has not yet been undertaken among swimmers of both sexes under the age of 16.

The physiological differentiation of women and men is based on the fact that the ability of generate mechanical power in men is definitely higher [9, 27]. What is more, boys aged 13 and above achieve significantly higher results in power tests than their female peers [28]. Thus, it is not surprising that in the given study, the boys obtained better results both for the CMJ and the SJ. Both trials have been described using several variables, despite the fact that some authors (among others, Trzaskoma [9] and Mazur-Różycka [29]) point to a significant correlation between individual jump indicators of one type, including mechanical power and jumping height. Inclusion of a larger number of variables characterizing the CMJ and SJ in the analysis was based on the hypothetical possibility of differentiating the strength of dependence between individual jumping variables. It is known that this type of dependence will affect, among others, the depth of lowering the centre of mass before performing the rebound or the technique of performing the attack [9, 30]. Therefore, it was decided to look for relationships between the swim start time (t_{10}) and six indicators from the CMJ and SJ trials. In this study, the interpretation of the on-land power test results was also hindered by the fact that the subjects performed the trial barefoot. This was decided for in order to increase similarity to swim start conditions. It can be assumed that this has affected the value of all indicators characterizing vertical jumps of both types. As stated by LaPorta et al. [31], the value of the discussed indicators is influenced by the subjects' footwear or lack thereof. Unfortunately, apart from this work, only in the methodology of Benjanuvatra et al. [10] was it noted that the subjects performed such tests without shoes. In other studies [2, 13, 18-20, 25, 26], it was not mentioned whether on-land power tests were performed with or without shoes.

In the search for relationships between the start time and the results of the CMJ, it turned out that none of the indicators create such correlations (in boys and girls). This gives rise to the assertion that the technique of performing the CMJ and starting jump differ so greatly that the described on-land trial should not be a test of the lower limb power referring to start jumps. Such a claim finds full support in the results of the work by Benjanuvatra et al. [10]. This team of researchers reached similar conclusions when conducting research among athletes with varied levels of sport competition.

When discussing the relationship between t_{10} and SJ performance results, the greater similarity of initial positions in both movement tasks (flexion in the lower limb joints) should be emphasized. Their external image is more similar than in the case of comparing the CMJ with the starting jump. Therefore, it should be assumed that the results of the on-land test (SJ) can be reflected in starting jump performance. It should, however, be noted that a similar observation was not made by, among others, Benjanuvatra et al. [10], while the research team led by Garcia-Ramos [19], determined that there is a relationship between the results of SJ and the start time up to 10 m. Nonetheless, in the publication, attention was drawn to the fact that the starting jump, as a technically complex task, is not related to a simple correlation with the power generation capacity of the lower limbs. It seems that female swimmers should first focus on the technical aspects of the starting jump, such as improvement in start reaction time, respectively high hip elevation on the block and extension in the hip joints in the final part of the push-off phase. In their case, power training of the lower limbs on land should only complement the training process. That is probably why Breed and Young [18] postulate that swim start technical training should be simultaneously performed with on-land training.

In the case of boys, almost all values of variables from the SJ were significantly related to t_{10}. One of the reasons for the lack of correlations between the SJ trial and the t_{10} in girls, but their occurrence in boys, can be found in the level of technical mastery and differentiation in performing the starting jump by swimmers of both sexes. It seems that, in boys, due to better technical training (which can be manifested, among others, by the time to overcome the 10-m distance), the mechanical power of the lower limbs could become a factor affecting start time (t_{10}).

In the SJ jump among boys, stronger relationships with the start time to 10 m were recorded for absolute variables (jump height, maximal speed, maximal and average power). In addition, the relative power indicators were found to be less correlated with start time. On this basis, it can be assumed that start time can also be conditioned by somatic build. It seems reasonable to claim that studies on individual conditions of a swimming start should take not only physiological but also anthropometric variables into account.

The analysis of results of this study seem to indicate that on-land lower limb power training can positively influence swim start time. Such a thesis, however, seems to be true only in the situation of swimmers' sufficiently high technical level. Additionally, it should be borne in mind that it is not possible to replace the technical training of jumps with exercises on land, which is also mentioned by, among others, Breed and Young [18]. Complete utilization of lower limb power during the starting jump is only possible when a proper amount of training is devoted to technical practice of swim starts [19] This means that improvement in the start time will only be possible when on-land power training of the lower limbs is combined with typical technical starting jump exercises.

Conclusions:

1. The relationship between on-land lower limb mechanical power tests and the time of the swim start is stronger in the case of boys.
2. In the group of young, male swimmers, significant relationships were noted between swim start and the absolute indicators for the SJ.
3. The CMJ with arm swing is not a valuable tool to assess the quality of starting jump performance.
4. In the training of girls, focus should first of all be on the technique of performing the jump, and after improving technical skills, it should be supplemented with on-land power training. The boys, due to the better quality of the jump start, can support technical starting jump exercises with on-land training aimed at increasing lower limb power.

5. The technique of performing the starting jump should be based on both assuming correct position on the starting block (high hip elevation) as well as taking proper correlations between flight time and length into account.
6. Kinematic indicators for the swimming jump of both male and female swimmers were significantly different. The boys recorded a shorter start time to cover the first 10 m, higher values for flight time and length as well as the height of the hips on the starting block and the angle in the hip joints during push-off.
7. Discrepancies in the technique of performing the starting jump between girls and boys result from different body structure and gender differences at the level of mechanical power of the lower limb muscles.

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