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*The effect of the type of turn on the level of kinematic indexes
of the glide stage in breaststroke*

**Wpływ rodzaju wykonywanego nawrotu na poziom wskaźników
kinematycznych fazy poślizgu w stylu klasycznym**

Key words: swimming, glide stage in breaststroke, turn, sports level

Słowa kluczowe: pływanie, faza poślizgu w stylu klasycznym, nawrót, poziom sportowy

INTRODUCTION

Just like with any other sport discipline, the swimming regulations that precisely specify the structure of each swimming style are being continuously changed. These conditions are cyclically updated every 4 years FINA (Fédération Internationale de Natation, the International Swimming Federation). When the evolution of swimming techniques is followed, one may notice that breaststroke has been transformed in the most thorough way, the style that is perceived by both theoreticians and practitioners as the most difficult and the least economic swimming style [1]. FINA made radical changes in the regulations at the turn of the years 2013–2014, which were related to, among others, the structure of the movement during the execution of the glide stage in breaststroke after the start and the turn. Initially after the start and after each turn the swimmer had to execute one movement of the arms entirely backwards towards the legs and a single butterfly kick, which was allowed only and solely during the first movement of the arms (online source no. 1). At present, apart from the movement of the arms, the butterfly kick may be done at any moment of the glide (online source no. 1). These changes resulted in swimmers currently using various combinations of coordination of the upper and lower limbs during the glide stage in breaststroke.

The full use of the turn stage may [7, 9] constitute from 20.5% to 44% of effectiveness of the total race, which is why the full use of the glide stage is so important. Considering this, one may notice that the glide is very important in all swimming styles, thus its biomechanical studies aimed at increasing its effectiveness also turns out to be very significant.

This observation currently constitutes the giant interest of professional swimmer circles. The said element of competition, the glide stage, according to the trainer of the Italian Olympians, Mica Marica [13], brings about better results than so-called “clean” swimming on the surface of water. This may be also confirmed in the statistics of the ranking list of world records in a 25 m swimming pool, during which there are more turns than in a swimming pool that is twice as long. Numerous studies prove that the properly executed start and turn have major affect on the sport result in sprint events.

Effectiveness of the race components of the glide stage is assessed as the time achieved by the swimmer during the first 15 metres after the start jump and the turn [2, 3, 23]. It provides the trainer with the necessary information about the function level and in particular about the technical level of the swimmer.

Analysis of effectiveness of the glide stage during the turn as one of the factors that may affect the sports result has become inspiration for the authors to initiate detailed observations in this matter.

OBJECTIVE AND STUDY QUESTIONS

The basic objective of the presented observations was an attempt at determination of the effect of the executed type of the turn on the level of the analysed kinematic indexes in the technique of glide execution in breaststroke.

STUDY QUESTIONS

- What changes occur in the values that describe the glide during various types of turns in reference to gender?
- Which of the analysed turns executed by female and male swimmers featured the highest kinematic values that describe the given turn?

MATERIAL AND STUDY METHOD

The basic study method implemented in the presented analyses was the direct and indirect observation method. The study was conducted with 12 sports practitioners of swimming in the Sport Mastery Secondary Schools in Krakow and with students from the swimming section of AWF Krakow. The study involved the total of 12 persons: 6 females and 6 males, aged 16 to 24. The subjects presented a varied sports level, but observations were applied only to the male and female swimmers with at least 2nd sports class certificate.

The basic subject matter of the detailed observations were the turns executed by female and male swimmers. They were executed in accordance with the FINA Swimming Rules. The objective of these studies was underwater recording of swimming turns in breaststroke and measurement of kinematic indexes of the swimmer's body during the glide, after completion of this technical element.

Before starting the recording, the swimmers had 9 points marked on the skin with a permanent marker pen (waterproof) that corresponded with the axes of joints of the lower and upper limbs. As a result, the location of the above places on the body could be precisely reproduced during the analysis of the film material. Specific male and female swimmers then started in succession their warm up and the proper recording of turns. Each one of them executed 9 attempts at the maximum speed, with short (not in excess of 1 minute) rest breaks between the consecutive repetitions. Whistle sound was used to mark the start, and the place where the test started was about the middle of the length of the swimming pool, that is ca. 12 m from the turn wall. The duration of whole study did not exceed 15 minutes, with the total duration of recording of the movement not in excess of 2 minutes.

The main objective of the work was the analysis of recording of the glide in breaststroke, thus it was also necessary to study the second turn executed in medley swimming, where the change is done after coming with backstroke to breaststroke. Swimmers use two types of turns during the race, thus recording of both of them was necessary: open and flip.

- The first three (so-called open) turns, as it has been stated, were executed to breaststroke. They consisted in touching the wall with both hands, and then simultaneous bending in the elbow joints and drawing the legs to the trunk and turning the shoulders and rotating the body. The last stage of the turn was the push off and transition to the recorded glide stage.
- The next three (so-called open) turns were used in medley swimming. The swimmer, after coming in backstroke, touched the wall with one hand while on his/her side and with drawing of the lower limbs to the wall the push off was executed and the glide to breaststroke.
- The last three (so-called flip) turns were also executed in medley swimming. They differ from the previous one in that the swimmer after reaching the wall in backstroke throws the lower limbs upwards (just like in a backward roll) and moves to the glide stage.

Film recording of three types of turns was done with the Casio Exilim EX-FH25 camera that meets all the requirements set for the devices used in the subsequent biomechanical analysis of movement. Films were recorded with frequency of 120 fps, with shutter opening time equal to 1/800 s. Further on, using the SkillSpector v. 1.3.2 software, the position of the main limb joints and the position of specific points of feet, head and hands were marked on the films. Its aim was to use one of the

models developed by the creators of SkillSpector with the name of Full Body Left-Side.

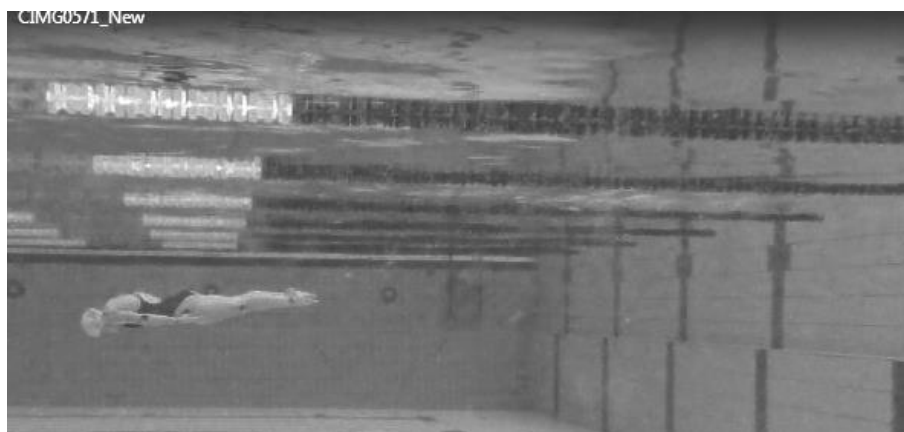


Figure 1. The studied female swimmer in the final position for video registration (the end of the full glide in breaststroke)

After filming all participants, the underwater recording of the image of the calibration frame in the course in which measurements of swimmers were taken was done. The frame was in the shape of a 1 m x 2 m rectangle. This element of the study was necessary to obtain information in the further stages of processing of the films about the actual moves of the bodies of swimmers and derivative variables (speed and acceleration of the centre of mass).

All the films were processed in the said SkillSpector programme. After marking on each frame of the film of the earlier stated points of swimmer bodies, the so-called calibration was conducted. This action consisted in marking, in succession, of the corners of the recorded frame and assigning the actual dimensions to it, which allowed to unanimously determine the scale of the images.

The graphs(charts) were obtained with the said SkillSpector v. 1.3.2 software for the following kinematic parameters of the movement of the swimmer in the stage that was the subject matter of the analysis(the glide). The following were determined on their basis:

- the maximum resultant speed, during the glide (V_w) in [m/s],
- the duration of execution of the glide (t) in [s],
- the maximum immersion of the swimmer (h_{max}) in [m],
- the duration of contact of the feet with the wall (t_{od}) in [s],

- the mobility of knee joint in the direction of movement, during the push off (ΔK_{ol}) and its maximum bend, in degrees [deg].

The individual values of the variables characteristic of each type of turn constitute arithmetical means of the variables (V_w , t , h_{max} , t_{od} , ΔK_{ol}) from the three successive attempts of this element of the technique. The values calculated in this way were used to determine arithmetic means in various groups of swimmers, these being in turn subjected to the descriptive statistics in the MS Excel program.

The values of the arithmetic mean (\bar{x}), standard deviation (SD), coefficient of variability (CV), range (R) were calculated in it and the minimum (min.) and maximum (max.) values were indicated.

RESULTS

The obtained results were put in Figures 2–5, which present the descriptive characteristics and the mean values of the studied variables: the resultant speed during the glide (V_w), the duration of execution of the glide (t), the maximum immersion of the swimmer (h_{max}), the duration of contact of the feet with the wall (t_{od}), the angle of bending of the lower limbs in the knee joints (ΔK_{ol}).

Figure 2 presents the summary of arithmetic means of the speed of the glide (V_{odk}) after each of the three studied turns, taking into consideration the results of both genders.

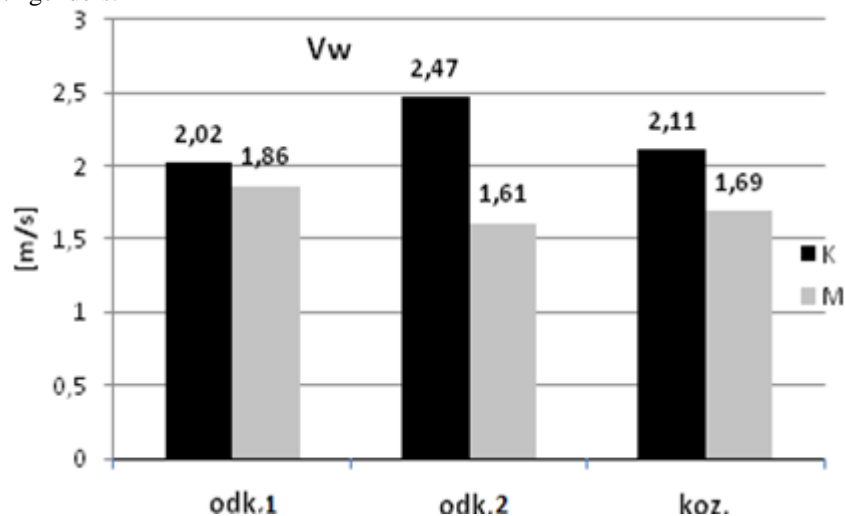


Figure 2. The mean values of the maximum speed during the glide (V_w) after execution of various types of turns in the groups of male swimmers (M) and female swimmers (K)

*Legend: V_w - resultant speed, during the glide in [m/s], K - females, M - males
 m/s - velocity, Odk.1 - the turn in breaststroke, Odk 2 - the turn in medley swimming, Koz. - the flip turn in medley swimming*

After each type of the executed turn (Fig. 2) females achieved higher values of speed during the glide; these values (V_w) exceeded 2 m/s on the average; whereas males were swimming this section evidently slower achieving from 1.69 m/s to 1.86 m/s. These results indicate also that female swimmers achieved the highest values in open turns 2.47 ($V_{w\text{ odk.}}$), and male in open turns to breaststroke 1.86 ($V_{w\text{ otw.}}$).

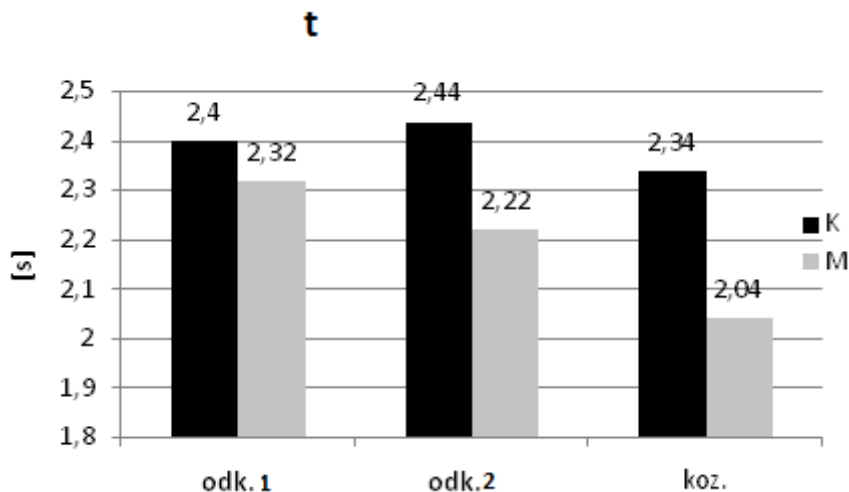


Figure 3. The mean values of the duration of the glide (t) after execution of various types of turns in the groups of female swimmers (K) and male swimmers (M)

Legend: t – the glide duration; s – the unit of time; K – females; M – males; Odk.1 – the turn in breaststroke; Odk 2 – the turn in medley swimming; Koz. – the flip turn in medley swimming.

The results presented in Figure 3 include the mean values of the duration of the glide (t) achieved after completion of various types of turns by female and male swimmers. Their analysis shows that this duration was in each case longer in females, and this difference from ca. 0.1 s (open turn to breaststroke), to 0.2 s (open turn to medley swimming), up to 0.3 s (flip turn). The presented results moreover indicate the observation that the type of the executed turn did not significantly affect the duration of the glide (t from 2.3 s to 2.4 s) in the group of female swimmers. In turn, the duration of the glide after the turn in the group of male swimmers (M) changed its length (by over 10% in extreme cases).

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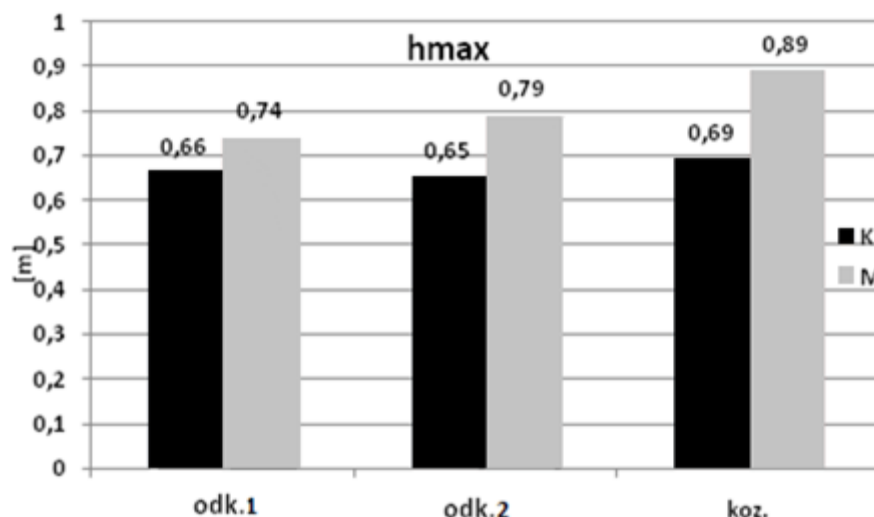


Figure 4. The mean values of the maximum depth of immersion OSC after execution of various types of turns in the groups of female swimmers (K) and male swimmers (M)

Legend: h_{max} - the maximum immersion depth of the swimmer; m - depth; K - females; M - males; Odk.1 - the turn in breaststroke; Odk.2 - the turn in medley swimming; Koz. - the flip turn in medley swimming

The mean values of the depth of immersion of swimmers (h_{max}) in the glide stage, after execution of the types of turns taken into consideration were put in Fig. 4. With the presented data taken into account, one may notice that this stage of the movement occurred in females at a smaller depth (from 0.65 m to 0.69 m) than in males (0.74–0.89 m). It has to be stated that irrespective of gender, after the flip turn the subjects executed the glide in the deepest depth of immersion from those recorded. Moreover the group of female swimmers executed this technical element within a considerably smaller range of variability; the values of the maximum differences of depths of immersion of swimmer (h_{max}) were 4 cm in females, with 15 cm in males.

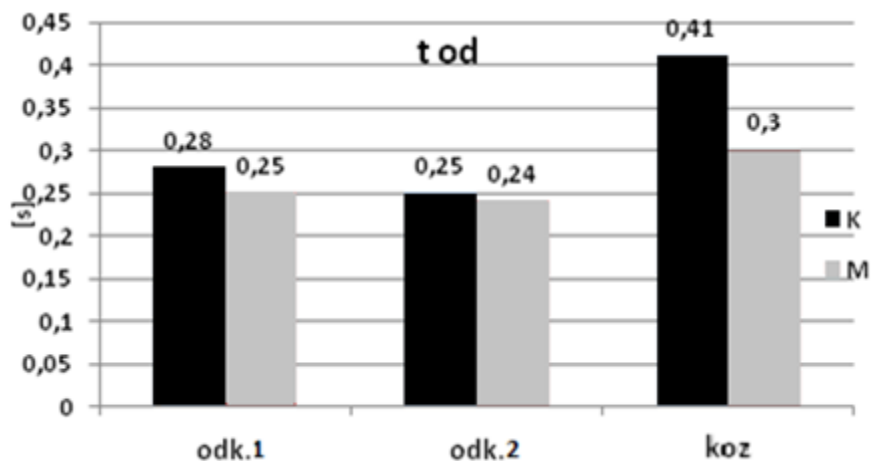


Figure 5. The mean time of push off from the wall (t_{od}) after execution of various types of turns, in the groups of female swimmers (K) and male swimmers (M)

Legend: t_{od} – duration of contact of feet with the wall; s – time; K – females; M – males; Odk.1 – the turn in breaststroke; Odk.2 – the turn in medley swimming; Koz. – the flip turn in medley swimming

Figure 5 constitutes the graphical illustration of the data that describe changes in the duration of push off from the wall of the swimming pool after completion of various types of turns. Both among females and males the mean values of the executed turns (t_{od}) differ from each other in the range of ca. 0.1 s and the discussed variable assumes the highest value for the time of push off after the turn executed, in the flip way. It is clear that this duration was in each case longer in females, and the differences in reference to the open turn in medley swimming and the open turn in the breaststroke-like style were minimum, being clearly marked in case of the flip turn.

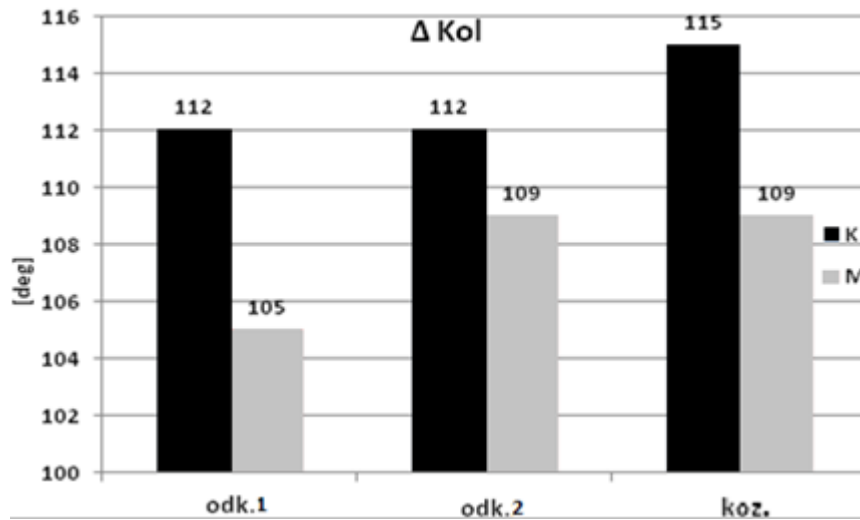


Figure 6. The mean values of the bending angle of the lower limbs in knee joints (ΔKol) during the execution of various types of turns, in the groups of female swimmers (K) and male swimmers (M)

Legend: ΔKol – values of the bending angle of the lower limbs in knee joints; Deg – degrees; K – females; M – males; Odk.1 – the turn in breaststroke; Odk 2 – the turn in medley swimming; Koz. – the flip turn in medley swimming

Figure 6 presents the characteristics of changes in the angle of bending of the lower limbs in knee joints (ΔKol) during the execution of turns in breaststroke and in medley swimming, in swimmers of both genders. The conclusion may be drawn that the differences of mean values were negligible, and the interval of the range of these changes was narrow (from 108° to 112°).

DISCUSSION

Assessment of the technique of execution of turns is a vital skill in the work of the trainer. It allows, among others, to determine the level of training of swimmers, as well as to verify the effects of the implemented training methods. Reduction of the total time of covering the swimming distance is achieved in the training process by way of increasing effectiveness of the individual sections of the swimming race, as argued by such information as: [5, 16, 20, 26]. Special role is assigned in this matter to perfecting execution of turns, because according to the calculations [7, 17] they may constitute as much as 20.5% of the time necessary to cover the distance of 50 m in a short swimming pool.

In this study, the obtained values in the groups of females and males varied considerably, with the similarly varied sports level of female and male swimmers. On

the basis of the biomechanical characteristics of the executed turn (speed, duration of glide, immersion depth, duration of contact of the feet with the wall, knee joint bending), it was observed that female swimmers execute turns in a way that is technically better than in a case of male swimmers. The conclusion may be drawn that the female group was a set of persons of higher sports level, which was manifested with better results achieved and higher sports class certification. Obviously enough, this observation is in no way surprising because the effect of training (and, in consequence, of competition experience) on execution of technical elements in sport is a phenomenon that is perfectly described and analysed [25].

The achieved results of the study as regards kinematic characteristics of the glide stage in breaststroke prove that the maximum speed of swimmers during the glide after completion of the turn, ranged from 1.61 m/s to 2.47 m/s. The values of the discussed variable given in the literature are discrepant. In some studies [6] authors place their lowest ceiling of the maximum speed of the glide stage at the level of 1.45 m/s. In other studies [16, 24] the range of the speed of the glide was defined between 1.6 m/s and 2.0 m/s. Other studies [12] bring about even higher range of speed. In this last case, the range of variability of the discussed parameter was assessed from 1.6 m/s to 3.1 m/s. The quoted review shows clear discrepancies of results. The said differentiation results most probably from the used measurement methods. However, one may add that results of own studies do not deviate from the results listed in the literature and are within the assumed range frames.

In case of another analysed component of the turn, according to Bartkowiak [4], contact of the feet with the wall has significant effect on speed of the glide. The value proposed by this author is 0.5 s and this time allows to use the force of push off of the legs from the wall. In turn Coosor et al. [6] obtained smaller values of the discussed variable in their studies, which amounted to 0.30 s in swimmers. In own studies, these values assumed the level of 0.18 s in female swimmers and 0.21 s in national level swimmers. Many authors finds the connection of the hydrodynamic position with achievement of high speeds. According to Marinho [14] the appropriate position of the body during the glide at the start and in the turn in sprint distances determines the success. Novaisi al. [16] are of the opinion that the skill of assuming streamlined body profile allows to reduce losing of speed. This skill is characteristic of high class swimmers. Slender body figure in case of women is the factor that naturally enhances minimisation of resistance [1, 10, 11, 27].

In own studies, it was found that the values of immersion during the glide oscillate within the limits of 70 cm in females. In turn, immersion of males after the turn was each time larger. The quoted values do not significantly deviate from the results that may be found in the world literature. At the same time, it has to be noticed that it brings about various information about the subject at hand, and these pieces of information are often contradictory. Webster *et. all* [28] and Maglischo [12], on the basis of own results, determined the desirable values of immersion for swimmers at ca. 0.4 m. In turn [13] indicate that swimmers should execute the glide at the level of 0.6 m under water to obtain the maximum benefits of reduction of resistance. Other data [18] define the threshold of 0.75 m, above which resistance values increase thus making gliding difficult. The same authors claim that below this value of immersion

diminishing resistance facilitates execution of the glide. According to Marinho [14], the deeper the glide is executed, the higher probability of improvement of its effectiveness, because water is there less turbulent, so moving in it is easier. It seems that this statement is accurate, but only in reference to highly trained swimmers.

The results of the study obtained in this work indicate that the type of the executed turn did not significantly affect the duration of the glide stage in females, but it significantly varied in case of males. It is commonly known that the purpose of the turn, apart from change of direction, is the additional use of the propelling impulse by way of pushing off from the wall and the underwater movement sequence (the butterfly kick and then the cycle of arms movement). The technically correct solution of this stage under conditions of its multiple repetition may decide about success and this is why swimmers should strive to perfect the glide. One can expect that the recorded differences in the duration of the glide in females and males most probably result from the different sports level of the subjects (and technical skills). In the light of the obtained results, one may also notice that the tip may be risked that practice perfecting the glide should be one of the main premises of training in case of the studied males.

The values of the kinematic variables that describe the flip turn, indicate its potential that may be used during competition. At the same time, technical complexity of the execution of this movement results in high dissipation of the obtained results and this is why attention should be paid in the training practice to increase the level of coordination skills. It is commonly known that the properly high level of this type of motoric skills is essential in mastering technically complex motoric acts [8, 21, 23, 25]. There are no doubts that this situation occurs in the discussed type of the turn.

Assessment of the glide in this work has been done in the aspect of three different turns. The decision about their choice during the race is based on the individual predispositions of the swimmer. The flip turn is undoubtedly the most effective, because its execution takes the shortest time. However, despite individual potential, it is rarely used by swimmers of low and medium sports level, due to large energy effort [15, 22]. The results achieved by the group of the studied female and male swimmers show that females developed the highest speed in the open turn. However, one has to remember that using it may be insufficient in the achievement of the intended objective, in the sprint distance of 100 m in medley swimming. Thus flip turns should be perfected in the training practice in female swimmers, which executed in a technically correct way take less time than open turns, as well as they do not cause major loss of speed. For this reason, the results of the presented study may constitute information for trainers to demand perfection and use of the flip turn in the training practice.

In own studies, it was also found that the duration of contact of feet with the wall was longest after the flip turn. It has to be stated that such a solution may be conducive to maximisation of the reaction force (the wall of the swimming pool), and it is known that this value is conducive to increase of the speed of locomotion [19]. Obviously enough, the image resulting from the analysis of gait or run requires some

simplifications in reference to, e.g., push off in swimming, but the mechanical sense of the phenomenon remains the same. It has to be stated that extension of the duration of the effect of the force of ground reaction, that is too long contact with the wall of the swimming pool, in itself does not lead in each case to the intended result (increasing push off speed). As it is known, the appropriate proportions of the individual phases of such movement have important significance in this case, as advocated by, e.g. Król and Młynarski [9]. It seems that too high values of the duration of contact of feet with the wall in the flip turn result from poor technical training of swimmers. This may manifest in, e.g. incorrectly executed approach to the turn wall. Such persons most probably execute the turn too close to the wall, which may result in leaving the feet on it for a longer time and, finally, reaching large angle values in knee joints. The presented results prove that the bending angle in knee joints in males exceeded 140° in individual cases. It is interesting to note, however, that the mean values of the discussed variable in females did not exceed 120° , with 110° in males. The stated values in the light of the reports [14] are typical and proper for the given event. The said author claims that bending angle in the discussed knee joint during the turn should be in the range of $90\text{--}120^\circ$ for the swimmer to be able to quickly push off from the turn wall.

The available literature is sparse in the matters of comparison of the effect of various types of turns on the level of kinematic coefficients in the technique of execution of the glide in breaststroke. Majority of articles are focused on the analysis of the selected turn. Some references to the parent work are present in the studies of Purdy et al. [20], where three types of turns in medley swimming have been analysed in the change from backstroke to medley swimming (open, flip, with throw of the lower limbs above water). Two variables were analysed in the quoted studies: the force of reaction of the feet with the wall and the duration of contact of the feet with the wall. The results of the study show that the highest force of the push off from the wall and the lowest value of the duration of contact of the feet with the wall were recorded in female swimmers in the flip turn [20]. The authors are of the opinion that the flip turn should be used by female swimmers because it is fastest. Additionally, a questionnaire study was conducted with the question for female swimmers which of the studied types of turns they use, it turned out that they mostly prefer open turn and turn with throw of the lower limbs above water, as they are simplest in execution.

The studies conducted for the needs of this work reveal differences in the level of technical training of female and male swimmers. It may appear that technical training still does not include (or includes too little) exercises for mastering swimming under water. In the light of the quoted conclusions, it seems to be of crucial importance to pay attention to the technical details of the executed movements.

CONCLUSIONS

On the basis of the conducted analyses, concerning the effect of the sports level of female and male swimmers and the type of the executed turn on the kinematic

characteristics of the glide stage in breaststroke the following generalisations have been formulated:

1. The higher sports level in the subjects was presented by females, as proven by the results of own studies, where females achieved higher speeds than males in each of the types of the executed turn.
2. The maximum speed of swimmers (V_w) during the glide after completion of the turn, assumed the values from 1.61 m/s to 2.47 m/s and was higher in females than in males in each of the executed types of turns.
3. In females, the highest speed was recorded in the stage of the glide after the open turn (2.47 m/s), whereas in males after the open turn to breaststroke (1.86 m/s).
4. The type of the executed turn did not affect the duration of the glide stage (t) in females, whereas in males this time varied distinctly. In the studied group of male swimmers the highest value was recorded after the open turn to breaststroke (2.32 s), and the lowest after the flip turn (2.04 s).
5. Immersion depth (OSC) in males after the flip turn (h_{max}) was 89 cm, whereas the values of the same variable recorded in females were lower and assumed 69 cm.
6. The duration of push off (t_{od}) from the wall was longest (both in females and males) after the flip turn and assumed, in succession, 0.41 s for female swimmers and 0.30 s for male swimmers.
7. During the butterfly “kick” during the glide, the larger range of movement in the knee joint was recorded in females than in males.
8. The values of the kinematic variables that describe the flip turn, indicate its potential that may be used during competition. At the same time, technical complexity of the execution of this movement results in high dissipation of the obtained results and this is why attention should be paid in the training practice to increase the level of coordination skills.

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STRESZCZENIE

Głównym celem niniejszej pracy była podwodna rejestracja trzech rodzajów nawrotów po których występuje faza poślizgu do stylu klasycznego a następnie analiza wybranych parametrów kinematycznych w technice wykonywanego elementu: maksymalną prędkość wypadkową (V_w), czas wykonania poślizgu (t) maksymalną głębokość zanurzenia pływaka (h_{max}), czas kontaktu stóp ze ścianą (t_{od}), ruchomość stawu kolanowego w kierunku ruchu, podczas odbicia (ΔKol) i maksymalne jego zgięcie, w stopniach [deg]. Do badań przyjęto 12 sportowców, 6 pływaczek i 6 pływaków z Zespołu Szkół Ogólnokształcących Mistrzostwa Sportowego w Krakowie oraz studentów sekcji pływackiej AWF Kraków w wieku 16-24 lat legitymujących się minimum II klasą sportową. Podczas badań zastosowano metodę bezpośrednią i pośrednią polegającą na rejestracji poślizgu, a następnie szczegółowej analizie wybranych zmiennych badanego elementu technicznego za pomocą oprogramowania SkillSpector v. 1.3.2. Uzyskane wyniki badań dowodzą, że pływaczki reprezentowały wyższy poziom sportowy odnotowując podczas każdego z badanych poślizgów większe prędkości pływania niż mężczyźni. Ponadto ich wartości były zbliżone do siebie, w przypadku mężczyzn zauważono znaczną rozbieżność uzyskanych wyników. W oparciu o wyniki zauważono, że zarówno kobiety i mężczyźni preferują podczas wyścigu stosowanie technicznie łatwiejszego nawrotu (otwartego) zamiast koziołkowego, który na podstawie przytoczonej literatury okazuje się być efektywniejszym.

ABSTRACT

The main objective of this work was underwater recording of three types of turns after which the glide stage occurs in breaststroke and then analysis of the selected kinematic parameters in the technique of the performed element: maximum resultant speed (V_w), glide duration (t) maximum immersion depth of the swimmer (h_{max}), duration of contact of feet with the wall (t_{od}), mobility of knee joint in the direction of movement, during push off (ΔKol) and maximum bend in degrees [deg]. 12 swimmers were included in the study, 6 female swimmers and 6 male swimmers, from Zespół Szkół Ogólnokształcących Mistrzostwa Sportowego (the Sport Mastery Secondary Schools) in Krakow and students of the swimming section of AWF Krakow of the age of 16–24 years, with at least 2nd sports class certificate. The direct and indirect method were used during the study, which consists in recording of the glide and then the detailed analysis of the selected variables of the tested technical element with the SkillSpector v. 1.3.2 software package. The results of the study prove that female swimmers presented a higher sports level than men in the recorded higher swimming speed during each examined glide. Moreover, their values were similar, significant discrepancy in the results was reported in case of males. Based on the results, it was noticed that both females and males prefer to use a technically easier (open) turn during the race instead of the flip turn, which proves to be more effective as reported in the literature referred to.

Artykuł zawiera 36637 znaków ze spacjami + grafika