

## SECTION – FUNDAMENTAL AND APPLIED KINESIOLOGY

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# THE ASSESSMENT OF RANGE OF MOTION IN SELECTED JOINTS IN COMPETITIVE SWIMMERS

## Authors' contribution:

- A. Study design/planning
- B. Data collection/entry
- C. Data analysis/statistics
- D. Data interpretation
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- F. Literature analysis/search
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**Keywords:** swimming, range of motion, hypermobility

## Abstract

**Background.** Differences in range of motion between groups of athletes specialising in various disciplines result from the specificity of these disciplines. Competitive swimmers spend many hours training, which affects motor characteristics, including flexibility.

**Objective.** To assess the difference in mobility of the joints: upper limb girdle, knee joint and ankle joint between groups of competitive swimmers and people who have never trained swimming or any other disciplines and, also, to determine whether there are any differences in range of motion in these joints between groups of swimmers specialising in various strokes.

**Material and methods.** 63 individuals aged 17 to 23 participated in the study. The subject group included 32 competitive swimmers (13 women), with at least 5 years of experience in competitive swimming and minimum 10 training units per week. The control group included 31 individuals (14 women) who were not engaged in any sports discipline (did not participate in more than 3 training units per week). Range of motion in the upper limb girdle was assessed using the Bloomfield test. Extension in the knee joint, dorsiflexion and plantar flexion in the ankle were measured using a goniometer. Inversion and eversion of the foot were measured using an instrument designed by authors.

**Results.** Greater mobility in the upper limb girdle and extension in the knee joint were observed in group of competitive swimmers compared to the control group. Measurement of ankle movement showed that female swimmers had greater dorsiflexion and male swimmers had greater plantar flexion than the controls. Inversion was slightly larger and eversion was smaller in the swimmer group.

**Conclusions.** Competitive swimmers had greater range of motion in the upper limb girdle and the ankle than the control group. Swimmers are also more likely to have hyperextension in the knee joint. Differences in range of motion between groups of swimmers specialising in various strokes were not noticed.

## Introduction

Swimming is a discipline recognized as one of the most beneficially affecting the human body. It is a particularly recommended form of recreation and rehabilitation. The benefits of this form of physical activity mainly result from the specificity of its aquatic environment. Floating in water or performing different strokes requires the involvement of many muscle groups. Overcoming water resistance develops muscle strength and endurance, and improves overall fitness by activating

the cardiovascular and respiratory systems. The aquatic environment is used in physiotherapy as a form of relief, especially recommended for joint pain or injuries when one should not be allowed to take on axial loads.

As a sports discipline, swimming requires a lot of effort and dedication. Competitive swimmers at the highest level spend dozens of hours a week in the water. Characteristics of the aquatic environment, techniques of movement in different strokes and multiple repetition of movement patterns require specific shaping of individual motor skills: strength, speed, endurance, co-

ordination and flexibility. The above-mentioned factors affect the range of motion in the joints of people practicing swimming, and as a result, can make it differ from physiological standards.

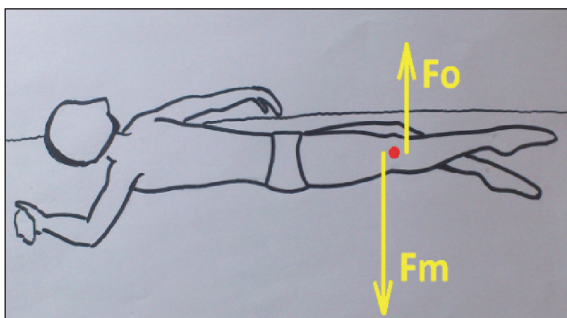
### Biomechanical factors affecting the range of motion in selected joints of swimmers

Swimming is one of the so-called “Overhead sports”, which require repetitive lifting of the arms above one’s head. Tennis, volleyball and all kinds of throwing disciplines also belong to this group of sports. High-level competitive swimmers perform 2,500 cycle repetitions per day in their main stroke. Annually, this number exceeds 500,000. The large range of motion in the shoulder joints required for swimming and the large number of repetitions are the main factors inducing pain associated with the girdle of the upper limbs. Numerous studies show that pain episodes within the shoulder occur in 40-90% of swimmers [1, 2, 3, 4, 5]. The mechanisms of injury in this sport can be different. To a large extent, they depend on the biomechanics of movement, characteristic of each stroke. Often the cause of pain is overloading the muscles, especially the rotator cuff and pectoral muscles. In addition, training focused on strengthening the muscle adductors and rotating internally, can lead to an imbalance of muscle tension. This may result in

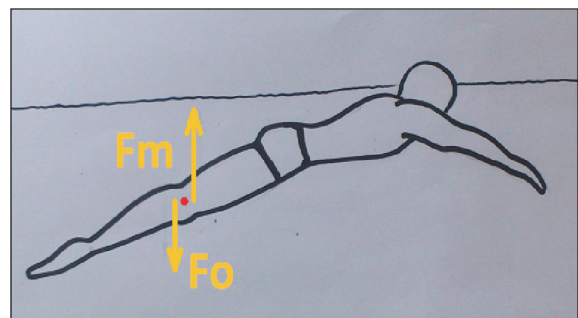
a reduction of dynamic stabilization of the shoulder joint. Instability, in turn, can cause subluxation and numerous micro-traumas, adding up during multiple repetitions of movements may even lead to labral tear [1].

Another joint susceptible to overloading in swimmers is the knee joint. Competitors specializing in the breaststroke are particularly vulnerable to these ailments. Most often, they complain of pain in the medial knee compartment, which may be associated with specific loads that occur while performing paroxysmal movements in the breaststroke swimming technique. According to studies, 86% of swimmers specializing in the breaststroke had an episode of knee pain at least once. It is reported that the risk of such episodes is five times higher for the breaststroke than other swimming styles [5]. Lopsiding the knee during paroxysmal movements can be the cause of pain on the medial side of the joint. Freestyle, butterfly and backstroke can also cause overburdening of the knee joints. When performing paroxysmal movements, maximum extension of the knee joint occurs, and water resistance forces acting on the limb intensify the extension (Fig. 1, 2).

The muscles straightening the hip joint act on the proximal part of the limb. Water resistance force, which have opposite turn to the force of hip muscles, acts on the entire surface of the limb: thigh, lower leg and foot.

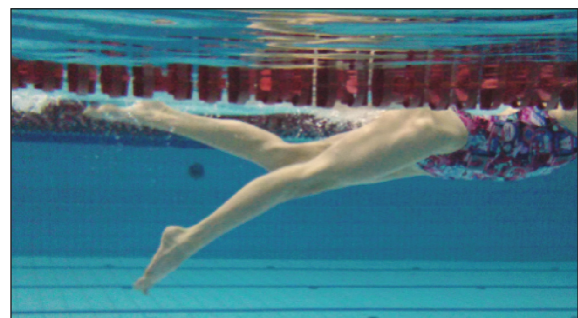


$F_m$  – muscle strength

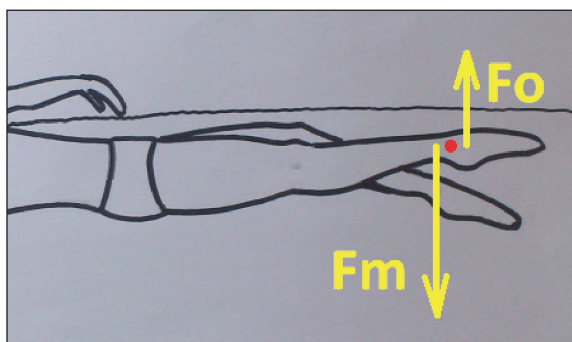


$F_o$  – water resistance force

**Fig. 1.** Diagram showing the forces acting on the knee while swimming the backstroke and butterfly



**Fig. 2.** Hyper-extension of the knee joint during the crawl stroke



Fm – muscle strength  
Fo – water resistance force

**Fig. 3.** Diagram showing the forces acting on the ankle joint while swimming the backstroke.

Resistance forces, acting distally to the knee joint, cause intensification of its extension. Multiple repetition of this movement may cause stretching of structures responsible for stabilizing extension in the joint.

Hyper-mobility of the knee joint can cause symptoms of pain in the back of the joint capsule and reduction of joint stability [6]. In people with hyper-extension, decreased proprioceptive control can be found, particularly in the final phase of the extension. This increases the risk of damage to the knee joint. In the research by J. Loudon et al. [7], it is suggested that patients with increased hyper-extension of the joint are five times more at risk of damage to the anterior cruciate ligament [8, 9]. Ramesh et al., conducted a study on a group of 169 people following ACL reconstruction in one knee. In this research 78.7% of the subjects presented hyper-extension above  $10^\circ$  in both knee joints. In the control group, which consisted of persons not declaring any knee joint pain, hyper-extension was diagnosed in 37% of the patients [10]. Hutchison et al. contend that hyper-extension in the joint leads to incorrect habitual posture because the excessive extension in knee is perceived as normal. Subjects presenting it, tend to take a standing position in which the knee joint is hyper-extended. This can lead to overburdening of the joint, related to non-physiological stance [11]. These reports suggest that hyper-extension of the knee joints increases the risk of both overload and acute injuries. Sudden injury can occur when an additional force acts on this stance, such as a blow, causing an increase in hyper-extension. The muscles are then not able to absorb the forces by increasing the tension or bending the knees quickly enough.

The proper execution of movements in various strokes are also dependent on hocks. Often competitors, especially during the warm-up, perform stretching exercises designed to maintain an adequate or even increase the range of motion in the joints [12]. According

to some researchers and trainers, while performing the downward kicking movement during the crawl stroke, the foot should be facing upwards and inwards as much as possible [13]. The forces acting on the ankle joint during movements of the stroke are similar to those acting on the knee joint and can cause a similar phenomenon of stretching certain anatomical structures. In this case, the resulting muscle strength and water resistance contribute to enhancing plantar flexion and inversion in the joint (Fig. 3).

### Study aim

The aim of the study was to investigate differences in mobility of the following joints: shoulder, knee and ankle, between a group of people professionally-training swimming and untrained persons, as well as to determine whether there are differences in mobility in those joints between swimmers specializing in different styles of swimming (breaststroke, backstroke, freestyle, butterfly).

The joints selected for the study were those whose mobility is determined by the correct technique of each swimming stroke: shoulder joints, in which flexibility is particularly exposed in the butterfly stroke, and hocks, determining the effectiveness of footwork in all of the strokes. The mobility of the knee joints was tested for specific loads, to which the limbs are subjected, especially during the butterfly stroke.

### Study material and methods

The study involved 63 participants who were divided into two groups: those training swimming (51%) and randomly selected untrained (in any discipline) individuals (49%). The inclusion criteria for the study group were among others: minimum 5-years training experience, the number of training units per week – minimum of 10, no injury that may affect the results of range of motion measurements. The study involved 57% men, and 43% women.

The study participants ranged in age from 17 to 23 years, mean age = 18.1 years. The individuals training and not training swimming did not differ among themselves in terms of age:  $t(61) = 0.12$ ;  $p = 0.906$ . The average body height of the subjects was 177 cm (155 cm min. and 201 cm max.), their body mass was an average of 69.3 kg (from 43 kg to 93 kg). There were no statistically significant differences between the two analyzed groups in terms of body height:  $t(61) = 1.37$ ;  $p = 0.177$  or body mass:  $t(61) = 0.99$ ;  $p = 0.327$ . The training experience of the subjects from the studied group ranged from 7 to 15 years, with an average  $M = 9.5$  years.

The dominating styles for 6 of the participants was the breaststroke, for 9 – the butterfly, the backstroke for 10 of them, and 7 specialized in the crawl stroke.



## Study methodology

Prior to testing, anthropometric measurements were taken, i.e. body mass, body height and shoulder width (distance *acromion-acromion*).

For the measurement of range of motion, the following were selected: upper-limb girdle, knee and ankle joints. The upper-limb girdle was examined using a test developed by J. Bloomfield in 1967. The subject moves his/her straightened arms upward in front, then behind his/her back while holding a stick his/her hands. The result of the test is the distance between the subject's thumbs which are clenched on the stick by their fists. The examiner makes sure motion abduction compensation does not occur during movement and sees to it that the movement was made symmetrically, without bending the elbow joints (Fig. 4).

In order to objectively compare the mobility of the girdle joints (to exclude discrepancy resulting from differences in shoulder width), the "Bark" (=shoulder) indicator was constructed (shoulder width [cm]/mobility of the shoulder [cm]).

Hyper-extension in the knee joint was measured with the Baseline 365° metal goniometer. During the measurement, the subject laid face-up on the couch, the lower legs not touching it. The dorsiflexion/plantar ankle movement was examined using the Baseline 365° metal goniometer.

The movement of inversion and eversion was measured using a self-constructed instrument, allowing to read data simultaneously from the two angular planes: transverse (movement around the vertical axis of the device) and the frontal (around the long axis/horizontal). The study was conducted in a lying position, the subject lying on his/her back. (Fig. 5).



Fig. 4. Range of motion measurement in the girdle of the upper limbs using the J. Bloomfield Test



Fig. 5. The measurement of inversion and eversion. Initial stance.

The lower leg of the subject was stabilized with the immobile parts of the instrument. Then, the subject was instructed to perform a movement of inversion (instruction: “bend the foot maximally towards the floor and turn inwards”) and eversion (instruction: “bend the foot maximally towards yourself and turn outwards as if you are trying to grab your little toe”). After performance of the movement, the examiner applied the movable part of the device to the foot of the subject, so that the line formed by the heads of the metatarsal was parallel to the surface of the board (Figs. 6, 7).

After applying the moving part parallel to the foot, the results were read from protractors. In order to facilitate the comparison of results of inversion and eversion, an index summing up the of angle results from the vertical and horizontal axes for these movements was created.

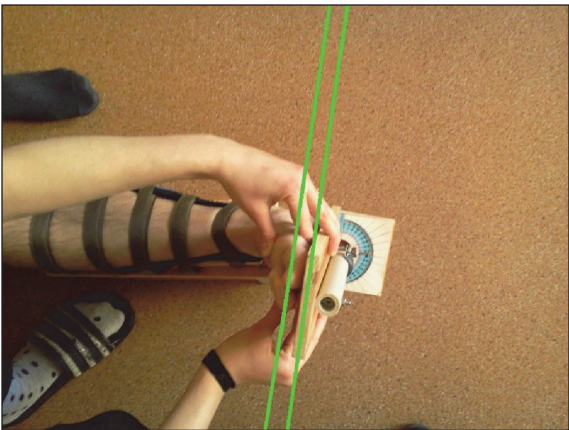


Fig. 6. Eversion measurement

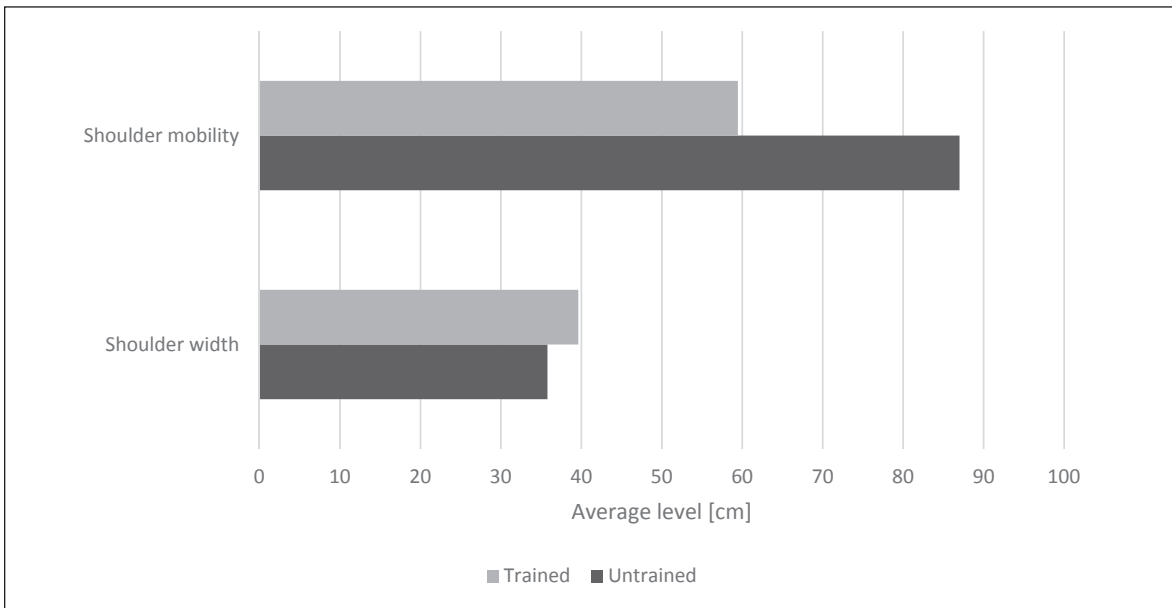


Fig. 7. Inversion measurement

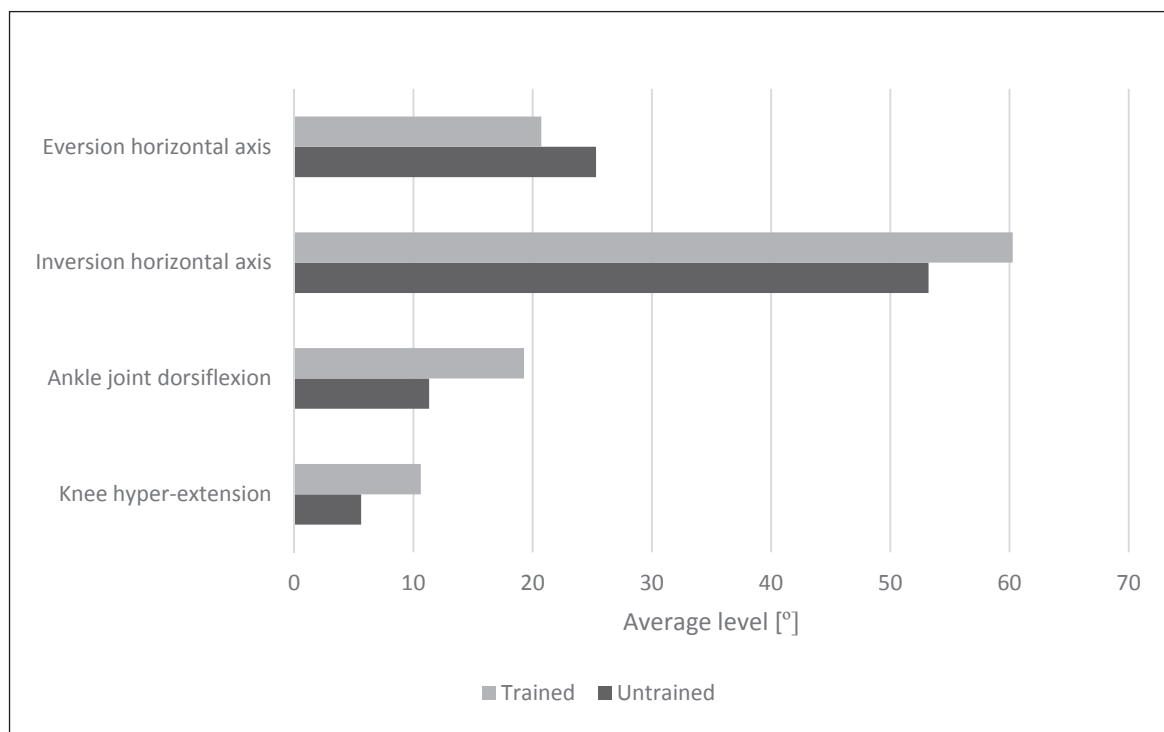
To ensure the reliability of the measurements, they were taken by a one examiner. The mobility in chosen joints was checked after a brief, individual warm-up. The subjects were instructed to make a few movements (5–10 repetitions) in each of the tested joints: swings in the shoulder joint, bending and straightening of the knee joint and abduction of the ankle joint.

### Results

Analysis showed that the women training swimming had a larger shoulder width by 3.8 cm ( $\alpha < 0.001$ ) and their mobility was higher by 27.5 cm ( $\alpha = 0.001$ ) compared to women who had no training in this sport (Diag. 1). No statistically significant differences were found between women with different dominant swimming strokes.



Diag. 1. The average level of upper-limb girdle mobility (cm) (lower results indicate better mobility) shoulder width (cm), women.



**Diag. 2.** The average level of individual measurement variables (°) in the studied groups of women

The same analysis in men showed no differences in shoulder width, however, they were noticeable in mobility: the average in the trained group was about 22.35 cm larger than the untrained ( $\alpha = 0.001$ ) (Tab. 1). No statistically significant differences were found between men performing different dominant swimming strokes.

It was found that women who trained swimming had a higher range of hyper-extension in the knee by 5° ( $\alpha = 0.018$ ), plantar flexion of the hock by about 8° ( $\alpha < 0.001$ ), inversion in the horizontal axis by 7° ( $\alpha = 0.035$ ), but lower levels of eversion in the horizontal axis by 4.6° ( $\alpha = 0.035$ ) compared to women untrained in this sport (Diag. 2). The analysis showed no statistically significant differences

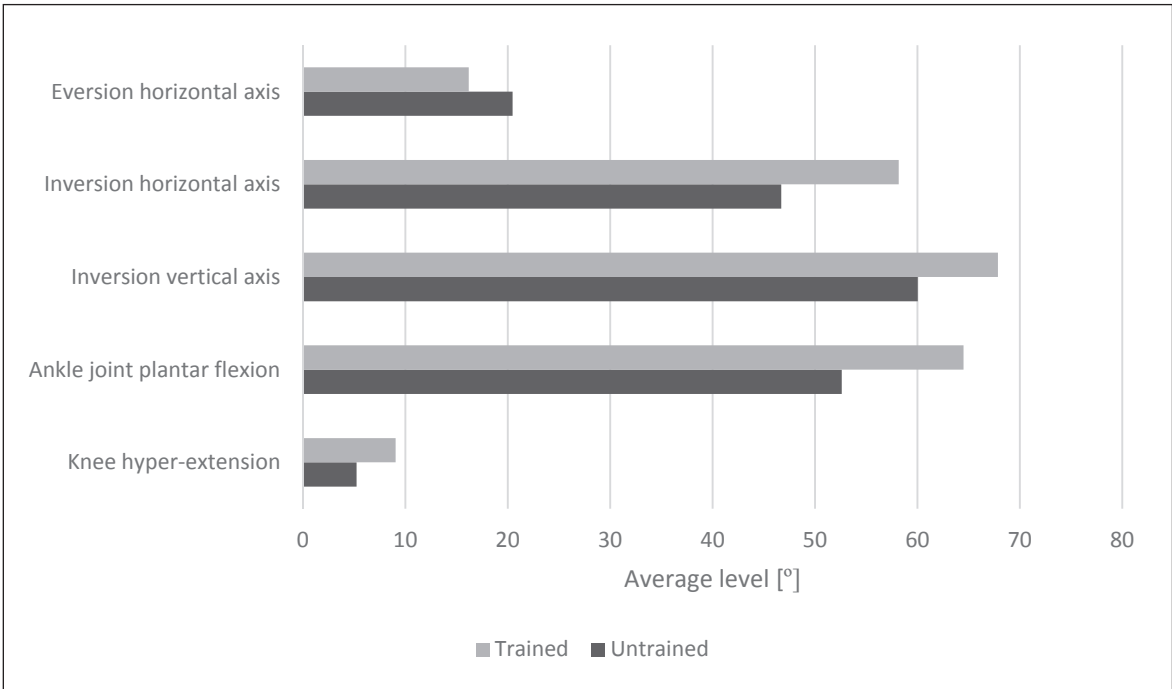
between women performing different dominant swimming strokes.

For the men, analysis showed that subjects training swimming had a larger range of knee hyper-extension by 3.8° ( $\alpha = 0.006$ ), range of hock plantar flexion by 11.9° ( $\alpha = 0.001$ ), inversion in the vertical axis by 7.8° ( $\alpha = 0.044$ ) and by 11.4° in the horizontal axis ( $\alpha = 0.002$ ), but a lower eversion level in the horizontal axis by 4.3° compared to men untrained in this sport ( $\alpha = 0.002$ ) (Diag. 3).

In the case of shoulder, inversion and eversion indicators – no statistically significant differences were found among women. However, in the trained men, the inversion indicator was higher by 19.3° ( $\alpha = 0.007$ ), and the shoulder indicator by 0.15° ( $\alpha = 0.001$ ) (Tab. 2).

**Tab. 1.** Descriptive statistics for shoulder width and upper-limb girdle mobility (lower results indicate greater mobility).

Variable	Swimming training	Average [°]	Standard deviation	Student's t-test result	Level of significance
Shoulder width	Yes	43.05	2.17	0.27	0.785
	No	42.85	2.18		
Shoulder mobility	Yes	77.00	19.93	3.62	0.001
	No	99.35	16.76		



Diag. 3. Average level of individual measurement variables in the studied group of men

Table 2. Descriptive statistics for individual indicators in the studied groups of men

Index	Swimming training	Average [°]	Standard deviation	Student's t-test result	Level of significance
Inversion	Yes	126.05	22.82	2.89	0.007
	No	106.74	16.29		
Eversion	Yes	33.74	9.83	1.32	0.195
	No	37.35	5.81		
Shoulder (width / mobility)	Yes	0.59	0.15	3.82	0.001
	No	0.44	0.08		

Discussion

Swimming is a discipline which strongly shapes all motor characteristics of a competitor. The aim of the study was to evaluate its impact on various ranges of motion in the joints. Research confirms increased mobility of selected joints in swimmers. The reason for this may be genetic predisposition of competitors to greater mobility of the joints. Wanivenhous et al., diagnosed constitutional joints hypermobility for 20% of swimmers [4]. According to various authors, Benign Hypermobility Joint Syndrome (BHJS) occurs in 4–43% of the population. Differences stem from lack of standardized diagnostic criteria, race, sex and age of the subjects [14]. Research conducted by a scientific team from Krakow

on a group of 96 girls aged 16–18 years, indicates that BHJS occurs in 28% of subjects diagnosed using the Beighton scale, and 45% when using the Bulbeny scale [15]. In the case of athletes specializing in other disciplines, a series of tests for diagnosing generalized hypermobility of the joints was conducted (Generalized Joint Hypermobility – GJH). This most often affects ballet performers – 97% of them were diagnosed with GJH [16]. Among the professional dancers, hypermobility was diagnosed for 66% of them. Soper et al., diagnosed articular hypermobility and 63% in those practicing netball [17], Decoster et al., 49% in lacrosse players [18] and Stewart and Burden 24% in rugby players [19]. Okamura et al. examined the occurrence of GJH in figure-skaters



(25.8% showed hypermobility according to the criteria adopted by the researchers) and speed-skaters (15.2% of the group presented hypermobility) [20].

There are ongoing discussions on BJHS and GJH diagnostic criteria. Dr. Kate Amon in her publication claims that diagnostic tools used to confirm BJHS (i.e. Beighton Score) needs to be improved. In her view, the Beighton Score may mistakenly diagnose BJHS in people who suffer from various types of pain in the musculoskeletal system of different origin [21].

In the case of the upper limb girdle, the appropriate scope of its mobility is necessary in order to effectively perform the technique of movements in different styles so as to minimize friction and increase efficiency of propelling movements [5]. This is probably because, among swimmers at a high level, the percentage of individuals with increased mobility of the shoulder girdle is greater.

From a British study group consisting of 453 children aged 9-18 years training swimming, gymnastics, football and tennis, the swimmers presented the greatest mobility of joints. Particularly large differences were seen in the mobility of the shoulder girdle measured using the "safety pin" test [22]. Our study confirms these results. The "safety pin" test and the Bloomfield test, although differing from each other, measure the global range of motion in the whole shoulder girdle (in the complex planes, in the left and right shoulder joint, simultaneously). For both women and men, the Bloomfield test results indicate greater mobility of the shoulder joint complex in swimmers compared to the untrained group.

The research conducted by Jansson et al. on mobility of joints in children is not so clear. The measurements were taken for 120 swimmers and 1,277 untrained children aged 9 and 12 years old. Using the Beighton scale, flaccidity of the joints was assessed with the drawer test, the stability of the shoulder joint was examined, and using the so-called Sulcus Test, its lower stability was tested. The internal and external rotation of the shoulder joint was measured goniometrically. The trained boys showed greater joint laxity than those from the control group, whereas the differences between the trained and untrained girls were not significant. Between the groups, there were no differences in the stability of joints in both girls or boys. However, among the young swimmers of both sexes, limitation of internal rotation was found, and for the trained girls, of external rotation as well. The divergence in the results of the study is probably due to the different ages of the subjects. Swedish researchers did not provide training experience or current frequency of training in the study inclusion criteria, which makes it difficult to compare the results [23].

Torres et al. conducted studies comparing internal and external rotation, and so-called GIRD (glenohumeral internal rotation deficit), thus an internal rotation deficit in

the shoulder joint of dominant limb in swimmers, tennis players and those untrained. Analysis showed no differences in external rotation between the groups. In contrast, internal rotation proved to be the smallest in tennis players and the largest in the untrained group. Similarly, GIRD: in tennis players, the difference in internal rotation between the non-dominant and dominant limb was 23°, for swimmers 12°, while in the control group, it was 4.9°. Reduction of internal rotation may be the result of a number of overlapping micro-injuries leading to contracture in the rear of the joint capsule. GIRD in tennis players results from the characteristics of the sport - the vast majority of over-the-head movements is performed by the dominant limb. Swimming is a sport in which work is performed by right and left forelimbs equally, yet GIRD may result from greater force applied to the movement of the dominant limb; however, it remains unclear if this is the case [1]. The present study demonstrated that global mobility of the upper limb girdle is greater in swimmers than in untrained people. The Bloomfield test checks the range of circumduction – which is a combination of flexion, abduction and external rotation, and so does not exclude restrictions on internal rotation in swimmers.

The present study showed that the range of extension in the knee joints turned out to be significantly higher in athletes training swimming. The measurements of the movement in swimmers are not very well described in scientific reports. The probable reason for the higher range of extension in the knees are the forces at work during propulsion movements during the freestyle, butterfly and backstroke swimming techniques. The forces broaden the extension of the joint, which extends ligamentous structures responsible for stabilization. Swimmers whose dynamic stabilization of the muscle is well-trained are probably less exposed to the consequences of non-physiological range of extension in the knee joint than people not engaging in physical activity. It is worth noting that the non-contracting structures (subjected to prolonged stress affecting their extension) have limited regenerative capacity (i.e. they regenerate little or not at all) and muscle stabilization regresses rapidly after cessation of exercise. It is therefore possible that the effects of hyperextensions in the knee joint – in the form of various types of overload pain, will be noticed only after cessation of the exercise.

The knee joint is, after the shoulder joint, the most frequent cause of pain for swimmers [4]. The frequency of structural and functional abnormalities in the knee joint is difficult to assess because they are not always associated with pain. The study conducted with magnetic resonance imaging on a group of young, asymptomatic swimmers showed at least one pathological symptom, visible in 69.2% of the swimmers. In the control group, the percentage was 32.1%. The illnesses



most commonly diagnosed with imaging were swelling of the Hoffa body fat and bone bruising within the femoral condyles, tibial plateau and patella [24]. The cause of pain in the front part of the knee joint can be found in patellofemoral joint degeneration, caused by frequent contractions of rectus femoris while performing the free-style, backstroke or butterfly stroke. On the other hand, breaststroke swimmers complain of pain in the medial side of the knee and their complaints about the knee joint are indeed the most common [4]. Pacey et al. report in their review article that generalized articular hypermobility is linked to knee injuries in athletes of various disciplines [25]. Bin AbdRazak et al., studied people following musculoskeletal injuries. Within this group, those with hypermobility were over three times more numerous than in the control group. Most often, they suffered from knee injuries [26]. The diagnosis of hypermobility is based, among others, on finding increased hyper-extension in the joint (above 10°). The range of movement was proved to be significantly greater in swimmers than in the control group, which may predispose swimmers to more frequent injuries.

The premise to explore the range of mobility of the talocrural and subtalar joints were reports suggesting that the likely range of plantar flexion and inversion affects the effectiveness of swimming. The results of research conducted by McMollough et al. show that swimming speed is only affected by greater plantar flexion and not greater inversion [13].

Another factor that may affect the mobility of these joints are the specific effects of muscle force and water resistance. Just as in the knee, they can affect extension of structures responsible for stabilizing the joint. The results of the present study indicate that the scope of plantar flexion in the talocrural joint is significantly greater in men training swimming than in those who do not train. In swimmers, it is also approx. 65°, while in those untrained 52°. The result does not vary in women – it is approx. 65°. Because women generally have greater joint mobility, it is possible that the range of dorsiflexion motion determines the performance of propulsion. Perhaps optimal mobility, allowing for proper movement techniques is approx. 65° and it does not differ from the physiological mobility in women, while it is optimized in men as a result of training. Similar with inversion – it is

higher in trained women, although statistically significant results were found only regarding the horizontal axis of the measuring instrument. The results of vertical and horizontal axes and the summing indicator of both axes were significantly higher in trained men and their values similar to those achieved by women (smaller only by approx. 2°). The range of eversion proved, in turn, to be lower in trained women and men as compared to those not training. Tests of statistical significance indicated only a smaller range of eversion in the horizontal axis as a valuable result, but this may indicate a tendency to limiting the range of this motion in trained men and women.

Comparison of the range of motion in specific joints, performed among swimmers specializing in various styles, showed no significant differences in the measurements. Biomechanics of joint work in during the freestyle, backstroke and butterfly stroke are similar. It is different in the breaststroke, which may suggest some differences in mobility of the joints. The lack of significant differences may result from the small number of subjects. Another reason for the lack of differences may be the fact that during training, swimmers always use strokes other than their primary ones. They use the front crawl especially during endurance preparation, largely because it is the most effective of all strokes in this respect.

The present study has shown that in most cases, swimmers demonstrate greater mobility of the joints than people not associated with this discipline. This is probably the result of long training, heavily influencing swimmers' organisms. However, since the range of movement affects the quality of swimming, there is a possibility that genetically predisposed individuals with greater mobility of joints, perform better in the sport and continue training at a competitive level.

## Conclusions

- People training competitive swimming have greater mobility of the ankle and shoulder joints.
- The occurrence of hyper-extension in the knee joints is more frequent in trained than untrained individuals.
- There are no differences in the mobility of the joints of the swimmers specializing in various swimming strokes.

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