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THE KINESTHETIC DIFFERENTIATION ABILITY OF TABLE TENNIS PLAYERS

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ABSTRACT
Purpose. The aim of this study was to evaluate the differences between two groups of table tennis players (differing by their level of play) in terms of the kinesthetic differentiation ability of their so-called spatial component. **Methods.** The study was conducted using a goniometer which assessed the accuracy of performing an arm movement, specifically, the pronation and supination of the forearm at the elbow. The study analyzed the accuracy rate of performing this movement, where a smaller value indicated a higher level of kinesthetic differentiation ability. **Results.** In all four tasks, the more advanced (skill-wise) group of players obtained lower arithmetic mean and median values of accuracy than the group that played at a lower skill set. This may suggest the importance of the tested variable as an important component of table tennis. However, the tested groups did not significantly differ from each other in the accuracy of performing the studied movement. Nonetheless, the variability of the accuracy rate of the lower skill level group was considerably larger than the more advanced and skilled group. **Conclusions.** It can be assumed that the more advanced group is more homogeneous in terms of accuracy production. This could be the result of specific training exercises.

Key words: kinesthetic differentiation ability, table tennis, precision of movement

Introduction

Kinesthetic differentiation ability is the total coordination of motor abilities. As found in literature on the subject, this ability allows for the perception and control of body movements. It enables one to have the conscious and accurate perception of the strength, timing and spatial parameters of a range of movement, which leads to various motor skills being more efficient and fluid [1, 2]. The essence of kinesthetic differentiation ability is its capability in positioning the body's joints (the spatial component), activating the strength of the involved muscles (the strength component) and the speed of the involved movement (the temporal component) [2–4].

Kinesthetic differentiation ability has been identified as one of the most important factors of motor coordination [2 ,3]. Previous literature has emphasized its importance in sport, but also stressed its complex and variable character which depends on a number of factors, including the difficulty in selecting which methods can be used to assess such an ability [5, 6]. Many studies have made reference to the fact that kinesthetic differentiation ability should be based on the ability (performance) level found in national sport competition and, as such, be considered in the selection process of sport disciplines.

Previous studies have also reported on kinesthetic differentiation ability and its relationship with the level of play depending on which sport disciplines were considered. Starosta conducted a study on figure skaters and found an interdependence between their kinesthetic sensibility and their skill level, and also showed that a higher skill level in sport is associated with greater movement accuracy (in performing specific moves) [4, 5, 7]. In addition, Zając et al., in a study of basketball players, found that an increasing level of competition is accompanied by a higher level of upper limb strength [8], confirmed by similar observations made by Ji and Huang [9]. Starosta et al. found a significant increase in the differentiation movement levels between the ready phase and start phase of kayakers, noting the strong relationship found between their differentiation ability level and the achieved sport results as well as their technical preparation [10]. Stefaniak, examining different martial art athletes, concluded that a higher kinesthetics differentiation level is characterized by a higher level of sport sophistication and that these athletes perform various motor tasks, which judge kinesthetic differentiation, far better than those who do not take part in competitive sport [11]. It was also demonstrated, through analysis on the relationship between the results of stress tests and force repetitiveness tests that kinesthetic sensitivity can be a useful tool in monitoring the training process in many sports [12].

According to the opinions of coaches and players, table tennis is a game in which the tactile sensitivity of one's muscles (and the "feeling the ball" that goes with it) is a very important aspect of this sport [13]. The importance of kinesthetic differentiation ability as well as all of its associated properties, defined as "sensation", is something that is paid close attention to by the authors of theoretical studies and training materials [14, 15]. These authors state that differentiation movement ability is critical in a number of table tennis game moves, such as the skill needed in feeling the rotation of a served ball, changing the direction of the ball during gameplay or modifying the speed at which a ball is hit (as well as adjusting to the movement rate and change in direction of the flying ball) [15]. Additionally, the selection and grip of a paddle at a specific angle (whether the paddle is "open" or "closed") is also a skill that has been connected to kinesthetic differentiation ability.

All of the above-mentioned skills heavily depend on the level of feeling and differentiation of muscle tone as well as the sensory control of arranging the individual parts of the body in gameplay and effect performance. What may also play a more prominent role here is the tactile-hold feeling of the hand (when holding the paddle). Thus, the differentiation of the spatial, strength and movement parameters in table tennis can determine many important aspects of player performance such as game accuracy, move capability, and the adaptation and control of game play. What is also clear is the importance of kinesthetic differentiation ability in shaping and improving a player's technique, which in table tennis is described as being very difficult and complex [14, 15]. Therefore, the study of kinesthetic differentiation ability and the ability to assess its significance in this discipline of sport appears to be of great importance.

However, there are few studies on kinesthetic differentiation ability or an assessment on the relevance of this ability in table tennis. The few studies that did consider this issues concluded that kinesthetic differentiation ability is a very individual ability, where, for example, no significant differences were found between various athletes (tennis and football players) and individuals who did not practice any sport [16, 17]. Similar studies found that the individual components of kinesthetic differentiation ability (strength, spatial and temporal) are relatively independent with no relationship to a player's age, and the stability of these parameters was also found to be very small. The level of each of these components was suggested to depend on the momentary physical, emotional and motivational disposition of an individual [18]. However, previous research conducted by the author of this study and other individuals did in fact suggest a relationship between kinesthetic differentiation ability and the level of play in regard to table tennis [19–21].

One of the components of kinesthetics differentiation ability is the measurement and performance of a range of movements through which one is able to optimally arrange the individual parts of their body [1–5]. Many studies that assessed kinesthetic differentiation ability used a method in which the accuracy of a specific range of movement was measured [2–5, 10]. As such, this study decided to adopt a similar method, and focus on measuring the forearm's range of movement in table tennis (whether holding a paddle in the "open" or "closed" position and the switch between backhand and forehand shots). It is hoped that measurement of the spatial components of kinesthetic differentiation ability, by also comparing and finding any connections with a table tennis players' level of play, could be a useful criterion in monitoring the training progress in table tennis. Therefore, the aim of this study was the evaluate the differences between two (differing in level of play) groups of table tennis players by comparing the level of their spatial components' kinesthetic differentiation ability.

Material and methods

Research was conducted on 24 table tennis players of varying skill levels. The players were divided into two equal groups: the first group consisted of participants from the Central Training Center for Table Tennis in Gdańsk (mean age 14.75 years) and the second group was composed of members of the Dolnośląski provincial team from Brzeg Dolny (mean age 14.08 years). Some of the table tennis players from Gdańsk were ranked in the top 12 in Poland in their age categories (cadet, junior). The team from Brzeg Dolny had four players in the top 16, while the rest of the players had a lower national ranking.

The study was conducted with the use of a goniometer in assessing the accuracy of performing a specific range of movement [2–5, 10]. The test stand (Fig. 1) was fitted with a specially designed device that allowed the subjects to pronate and supinate the arm from the elbow up (Fig. 2). This device consisted of a fixed housing with a movable handle. The handle could roll to the left or right and was connected by a Teflon bearing to a cylinder found inside the housing. A rotary potentiometer that registered force linearly was attached to the end of the cylinder, which would then record the change in position. The subject was placed in a sitting position on an adjustable chair and asked to grab the handle of the device in such a way that the forearm of the tested arm formed a right angle and so that the elbow was next to the subject's torso. In accordance with the requirements necessary to measure the range of movement [22], the experiment made sure that the forearm axis coincided with the movement axis and the top of the third metacarpal bone aligned with the rotation axis. The change in angle was recorded by a computer program (Labview ver. 2009, National Instruments, Poland), which was connected by a NI USB 6008 analog-digital card (National Instruments, Poland) to the cylinder.

The subjects were not allowed to familiarize themselves with the equipment. Each test subject in each of the series of tests was asked to perform only two tasks. The first task was performed blindfolded, where the subject was asked to pronate and supinate their dominating forearm (in a movement pattern) three times,

Figure 1. Test stand with goniometer

Figure 2. Goniometer

starting from an "intermediate position" (at an angle of zero degrees) and twisting their arm until they reached an angle of 45 degrees. Upon reaching the 45 degree angle a bell automatically sounded. The subject was then asked to immediately perform the same movement five additional times "from memory" (with the blindfold on but without the use of the bell). The subject was given a maximum of 30 seconds to produce the five repetitions. They then performed the same task with their non-dominant hand. The computer program logged the maximum range of movement in each direction through the "twist" angle produced by the test subject. The starting position of the handle was checked and adjusted by the author before each test.

The level of kinesthetics differentiation was determined for both the dominant and non-dominant hand by finding the accuracy rates of performing the set tasks, which was calculated as a standard deviation from the "set" 45 degree angle. For more in-depth analysis, the following variables were adopted: NP1 (pronate accuracy of the dominant limb), OP1 (supinate accuracy of the dominant limb), NL1 (pronate accuracy of the non-dominant limb) and OL1 (supinate accuracy of the non-dominant limb). A lower value in the accuracy rate of performing a movement pointed to a higher level of kinesthetic differentiation ability (specifically the spatial component of this ability).

Statistical analysis of the recorded results was performed using Statisca for Windows (Statsoft, Poland), descriptive statistics were calculated as well as statistical significance using the Mann-Whitney *U*-test.

Results

In all of the performed tasks, the group from the Central Training Center in Gdańsk was found with lower arithmetic mean (and median) accuracy rates than the group from Brzeg Dolny (Tab. 1 and 2, Fig. 3): for the supination of the dominant limb the arithmetic mean for the Gdańsk group was 4.55, while for the Brzeg Dolny group it was 5.96. For the pronation of the dominant limb the arithmetic mean for the Gdańsk group was 4.48, for the Brzeg Dolny group, 6.41. Similar differences were observed with the non-dominant limb. The arithmetic mean for the supination task in the Gdańsk group was 5.34, for the Brzeg Dolny group,

Table 1. The indicator values of accuracy (in degrees) of the Gdańsk group: the arithmetic mean, median, minimum, maximum and standard deviation

Variables	Number of subjects	Arithmetic mean	Median	Minimum	Maximum	Standard deviation	Coefficient of variation (%)
OP1 (supination of the dominant limb)	12	4.55	3.94	1.93	9.16	2.29	50.24
NP1 (pronation of the dominant limb)	12	4.48	4.30	3.07	6.77	1.25	27.86
OL1 (supination of the non-dominant limb)	12	5.34	4.55	2.46	9.50	2.23	41.75
NL1 (pronation of the non-dominant limb)	12	4.27	4.01	0.87	9.32	2.32	54.33

Table 2. The indicator values of accuracy (in degrees) of the Brzeg Dolny group: the arithmetic mean, median, minimum, maximum and standard deviation

Variables	Number of subjects	Arithmetic mean	Median	Minimum	Maximum	Standard deviation	Coefficient of variation (%)
OP1 (supination of the dominant limb)	12	5.96	4.87	3.20	14.58	3.17	53.17
NP1 (pronation of the dominant limb)	12	6.41	8.33	1.42	12.08	3.59	55.99
OL1 (supination of the non-dominant limb)	12	6.92	5.10	1.42	16.99	4.56	65.79
NL1 (pronation of the non-dominant limb)	12	7.84	5.10	1.69	44.76	11.75	149.92

6.92; the mean for the pronation task in the Gdańsk group was 4.27, for the Brzeg Dolny group, 7.84.

After applying the Mann-Whitney *U*-test, no statistical significance was found. The test results are shown in Table 3. The indicator values of accuracy of the Brzeg Dolny group are more diverse than the ones of the Gdańsk group, a group that plays at a higher level. This is evidenced by the much higher coefficient of variation in the Brzeg Dolny group, from 3% for OP1 to more than 20% for NP1 and OL1 and up to nearly 100% higher for NL1 than in the group from Gdańsk (Tab. 1 and 2). In all the tasks, the standard deviation (SD) for the values of accuracy were substantially higher in the group from Brzeg Dolny. Similarly, the difference between the minimum and maximum accuracy values were significantly higher in the Brzeg Dolny group than in the Gdańsk group.

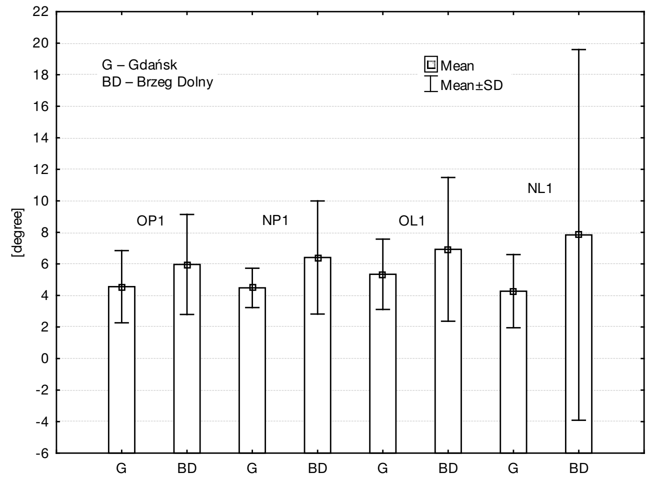

Figure 3. The results of performing a range of movement (in degrees) of the supination of the dominant limb (OP1), pronation of the dominant limb (NP1), supination of the non-dominant limb (OP1) and pronation of the non-dominant limb (NL1) of both the Gdańsk (G) and Brzeg Dolny (BD) groups

Table 3. The significance level (p) of the differences between the groups in the different tasks as calculated by the Mann-Whitney *U*-test. Statistical significance is $p \leq 0.05$

Variable	p level
OP1 (supination of the dominant limb)	0.24
NP1 (pronation of the dominant limb)	0.31
OL1 (supination of the non-dominant limb)	0.54
NL1 (pronation of the non-dominant limb)	0.47

Discussion

Research on kinesthetics differentiation ability (and its spatial components, differentiating the range of movement) is considered by many authors as an ability that is extremely important to accurately and efficiently perform motor functions [1–5, 7]. Its fundamental nature is the perception of movement while it is happening, allowing such a movement to be better controlled. Literature that studied and assessed the level of differentiation ability and its determinates and relationships often find that the level of this ability determines, to a large extent, success in many sport disciplines. Such a dependency was found by Starosta in figure skaters, by Starosta et al. in kayakers, by Zając et al. in basketball players and by Stefaniak in martial art athletes [4, 5, 7, 8, 11]. The high level of kinesthetic sensitivity found in these athletes especially applies to the particular body limbs most involved in that sport's physical movement: the lower limbs for figure skaters, the upper limbs for boxers or the lower limbs for karate practitioners [4, 5, 10, 11].

Ji and Huang also observed a high level of kinesthetics sensitivity in the hands and elbows of basketball players [9], which was similar to what Zając et al. observed [8]. Some researchers also claimed to find a relationship between kinesthetic differentiation and high-level training technique. Such dependencies were found by Cynarski et al. in karate practitioners [23], by Buraczewski et al. in football players [24] and by Starosta et al. in kayakers [10]. Also, many correlations have been found between kinesthetic differentiation ability and the level of sport played or advanced sports techniques used in gameplay; thanks to a high kinesthetic sensitivity one can more accurately control their movement [1–3]. In addition, through kinesthetic impression, the "focus" [2, 4, 5, 7] on one's bodily movement is far more fuller and richer, where the functioning of one's telereceptors is supplemented by proprioceptor stimuli [1]. Thanks to this "extra" information, learning new motor skills is more precise. However, as has been found in relevant research, the importance of visual and kinesthetic information is still disagreed upon [25, 26].

This study assumed that the sport of table tennis requires a high level of kinesthetic differentiation ability [15, 19–21]. This ability is manifested in table tennis due to the numerous skills needed to be effective in this game, above all, the ability to sense and adapt to game dynamics (the speed of the game, the spinning of the ball, correctly landing the ball on the table, etc.) [15]. Adjusting the angle of one's paddle when hitting a ball (something which occurs in a split second) most probably is also a derivative of kinesthetic differentiation ability. This study found a tendency to perform the required tasks better by the group with a better skill level. This trend manifested itself in the lower (and thus providing better accuracy) arithmetic averages (as well as median) values of accuracy. Such higher values (presented in this study as pointing to a lower kinesthetic differentiation level) were observed in the Brzeg Dolny group. However, these differences were found not to be statistically significant after statistical analysis. Nonetheless, the above-mentioned tendencies should lay ground for further research in this area, especially when considering the results of other studies that indicate the importance of kinesthetic differentiation ability in table tennis players [20, 21].

Some specific characteristic differences can also be observed in the analysis of the coefficient of variation and the size of the standard deviation of the studied variables, as well as the dispersion of the results in both groups. In addition, a greater variability of the results was observed in the Dolny Brzeg group, a group which had an overall lower skill level in table tennis; the group from Gdańsk was found to be far more homogeneous skill-wise. It may be postulated that this could be the result of more specific, time-consuming practice sessions as well as more all-round, varied training exercises which these players engage in.

Conclusions

1. Both groups did not differ significantly in the accuracy of performing a specific movement (as found by the test). In all four tasks, the more advanced group of players obtained lower arithmetic mean and median values of the studied variables than the group that played at a lower level. This may suggest the importance of this test in table tennis and lead to future studied performed on a larger population sample.

2. The variability and dispersion of the values of accuracy in performing a specific movement in group of players who are at a lower skill level was far greater than in the group which is more skilled. It can be assumed that the more advanced group is more homogeneous in terms of their accuracy. This could be the result of specific training exercises.

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