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The Use of Modern Measuring Devices in the Evaluation of Movement in the Block in Volleyball Depending on the Difficulty of the Task Determined by Light Signals

Kacper Cieśluk [1,†], Dorota Sadowska [2] and Justyna Krzepota [1,*,†]

[1] Institute of Physical Culture Sciences, University of Szczecin, al. Piastów 40B, Blok 6, 71-065 Szczecin, Poland; kacper.ciesluk@usz.edu.pl
[2] Department of Physiology, Institute for Sport—National Research Institute, ul. Trylogii 2/16, 01-982 Warsaw, Poland; sadowska.dorota@hotmail.com
* Correspondence: justyna.krzepota@usz.edu.pl
† These authors contributed equally to this work.

Abstract: The basic technical element that is a direct response to the opponent's attack is the block. Blocking is related to setting the starting position of the player and choosing the most effective way to move. The aim of this study was to evaluate the time of movement in the block depending on the difficulty of the task determined by a response to light signals. The study included 14 players (17.36 ± 1.18 years). Eight discs of the FITLIGHT Trainer™ device placed at different heights near the center of the volleyball court were used for the measurements. The player's task was to move as quickly as possible in a block after recognizing a light signal to take a specific action. Three types of tasks with different levels of difficulty were defined: reaction to the light signal on the player's side (S1), reaction to the light signal of the upper or lower discs placed vertically over the net (S2), and reaction to the color of the light signal of the upper or lower discs placed vertically over the net (S3). The following time measurements were analyzed: indirect time (TI), time of movement to the jumping point (TJP), and total time (TT) on the right and left sides. In all measurements (TI, TJP, TT), the differences in the times obtained in tasks S1 and S2 and tasks S1 and S3 were statistically significant ($p \leq 0.001$) for both the right and left sides. The comparison of the task performance times for S2 and S3 showed a difference only in the TJP measurement for the left side. An analysis of the results indicates a significant role of signal recognition and decision-making process in the player's movement during blocking. The FITLIGHT Trainer™ device can be a useful tool for this purpose in coaching.

Keywords: volleyball; block; FITLIGHT Trainer™; youth

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1. Introduction

The factors that determine the outcome in volleyball games vary depending on the sports skill levels of the competing teams [1]. These include, among others, quality and faults of service and reception [2] and scoring serves [3]. However, analyses of games between teams of similar or different sports skill levels have shown the effectiveness of the attack as the element that is critical to success in a game [1]. On the other hand, blocking is the basic technical element in the set of actions taken to prevent the opponent from scoring points during the attack [4]. The authors note that it is the first line of defense and provides a direct response to the offensive actions of the opposing team [5,6].

Depending on the offensive tactics of the opposing team and the setting direction and tempo, different systems and strategies of block play can be distinguished. Research by [6] showed that zone blocking yields greater benefits than man-to-man blocking and a middle blocker position marking the setter. Similar findings have been shown in other studies [7], recommending that middle blockers start the blocking action from the center of the net regardless of where the ball is set from. The behavior of blocking players can also be divided into a read-and-react playing strategy and an anticipation movement game strategy [5,8]. In the first strategy, players move to the block only in response to the set ball. In the anticipation movement strategy, players establish ready solutions even before the opposing team starts the action. This manifests itself by setting up a block in a specific zone of the court even before the ball is set. The starting positions of the blockers can also be aimed at the better organization of the block in specific zones of the court and influence the opponent's action. The pinched (near the center player), spread (near the sideline), or mixed (narrow on one side and wide on the other) positioning of opposite hitters translates into the distribution of balls set by the opposing team's setter [9]. Consequently, blockers can reduce the effectiveness of the opponent's best actions and make it necessary to play using other variants. Based on the offensive tactics of the opposing team and the setting direction and tempo, different systems and strategies of block play can be distinguished.

One of the objectives of previous research assessing the quality and effectiveness of a volleyball block is distinguishing the different ways in which the player moves from the starting position to the jump position. Research shows that when moving on the court, athletes use a slide step, a cross-over step, or a running step, and various combinations of slide and cross steps [10–14]. The means of movement are determined by the player's specialization, individual preferences, training experience, and the zone of the court in which the block is performed [12,14]. One of the main elements explored in previous studies was the speed of movement of the various techniques. Research [14] showed that although as many as four means of performance can be defined in the cross-over step, they do not differ significantly in terms of the speed of performance. However, it has been observed that in the first phase, the most effective method is the cross-over step, consisting of two steps. In other studies [10], the authors observed faster performance of the whole movement with a cross-over step by opposite hitters compared to middle blockers. Furthermore, it was shown that all players were performing the movement faster to the right side. Research related to moving in the block also aimed at comparing lower limb movements depending on the direction of movement and the athlete's laterality. The authors compared the movements of the lead limb and trail limb at landing after moving in a block in the dominant and non-dominant directions, and they also compared situations where the dominant and non-dominant limbs performed the same roles. It was found that different movement strategies were used depending on the role that the lower limbs play [15]. The focus of a study of moving in the block also included the work of the upper limbs. The results showed that there was no difference in movement time regardless of the technique used [13]. However, choosing the appropriate technique can improve other parameters that can affect the effectiveness of blocking. The use of the chicken wings technique reduced the time to take off when jumping, while the full swing technique resulted in a beneficial effect on jump height, better hand penetration over the net [13], higher vertical and horizontal velocity, longer hand-over-the-net time, and greater blocking area [16].

Despite the evident benefits of volleyball training focused on improving motor fitness performance, the results of current research show the increasing importance of visual–perceptual–cognitive functions [17–23]. Volleyball is a demanding and complex sport in which decision-making skills are often a key component of the actions taken [24]. From this perspective and in light of the research results, developing perceptual–cognitive skills is an important training method to improve fundamental skills such as anticipation and decision making [25]. Consequently, research on decision-making [26,27] or anticipatory skills [28] based on the verification of visual behavior is a rapidly developing area in volleyball.

Researchers have documented that volleyball players with better basic cognitive functions are characterized by higher sports performance [17], while studies on the anticipation, decision-making, and pattern recall skills of players of different ages showed that all these perceptual–cognitive skills improve with age [19]. Recent reports further indicate that between men and women, the results of most perceptual–cognitive indicators (selective attention, simple reaction time, complex reaction time, sensory sensitivity) show non-significant or small-to-moderate differences between genders [21]. Finally, it should be emphasized that the assessment of cognitive function along with the evaluation of volleyball-specific indices can be an effective method to discriminate players of different competitive levels [18]. There is no doubt that in volleyball, both vision [22] and reaction time [29] are fundamental components, because players must process visual information and, based on this, make the appropriate decisions and display fast reactions as a response to the opponent's behavior. A recent systematic review revealed that the perception of salient information actuates the decision-making process [30].

Taking into account that the complexity of the stimuli when evaluating visual signals that determine the decision to perform a block may affect the actions taken by young athletes, we hypothesized that increasing the difficulty of the task determined by the light signal would increase the movement time of the player in the block. Therefore, the aim of the present study was to evaluate the time of moving in the block depending on the difficulty of the task determined by light signals. The specific objective was the evaluation of the time of moving in various phases of the block: (a) intermediate time (TI), (b) time of movement to the jumping point (TJP), and (c) total time (TT).

2. Materials and Methods

2.1. Participants

The study involved 14 volleyball players from the UKS "Błyskawica" Szczecin club. The age range of the participants corresponded to the U18 (16–17 years) and U20 (18–19 years) categories. The mean age of the participants was 17.36 ± 1.18, with training experience of 3.79 ± 2.19. All study participants and their legal guardians were informed about the study procedure. Written, informed, and voluntary consent to participate in the study was obtained from adults and from legal guardians in the case of minors. Written permission from the club president was also obtained at the request of the authors.

2.2. Testing Procedure

The player's task was to move as quickly as possible in the block after recognizing a light signal to take a specific action. To unify movements, the participants were instructed to move in a block with a slide step facing the net. The FITLIGHT Trainer^{TM} system was used in the test. Eight light discs were arranged at different heights around the center of the volleyball court (Figure 1). The placement of the lower discs (6), (4), (3), (5) was as in previous studies [31].

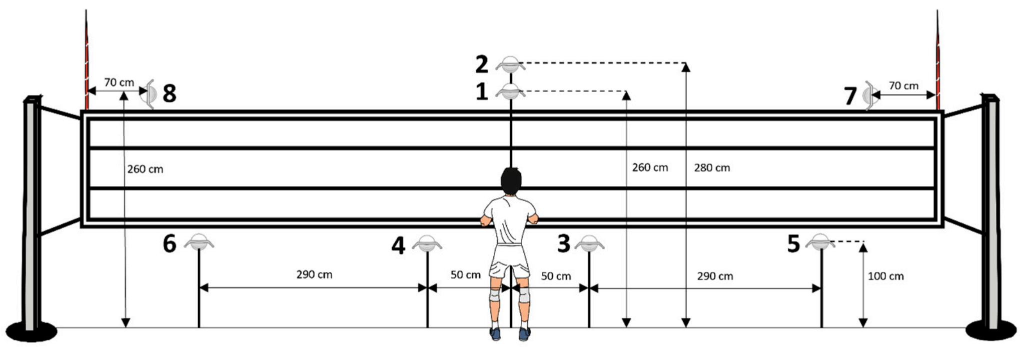

Figure 1. FITLIGHT Trainer^{TM} light disc arrangement. Discs (1)–(6) were facing the participant. Discs (7) and (8) were positioned along the net, with their backs towards the closer antenna and sides towards the participants.

The measurement procedure was preceded by a 10-min warm-up. Next, the participant was given detailed instructions on how to perform the task. The athlete started with the starting position standing on the axis of the court at the net in a position of readiness for a block. After the light signal was displayed, the participant's task was to recognize the signal (S1, S2, or S3) as quickly as possible, move from the starting position, and finish the action by jumping to the block on the right side opposite the disc (5) while crossing the disc light beam with the hands (7), or on the left side opposite the disc (6), also crossing the disc light beam with the hands (8). The test procedure included 36 measurements recorded for each athlete with a repetitive pattern that consisted of 4 sequences (12 movements to a block) performed three times (each followed by a 5-min rest break) (Figure 2). Work and rest times were adjusted to model actual game situations in experimental conditions. Providing a break between performing consecutive blocking actions was necessary due to the required rotation and taking into account the usual time spent by a player in the defensive line or off the court.

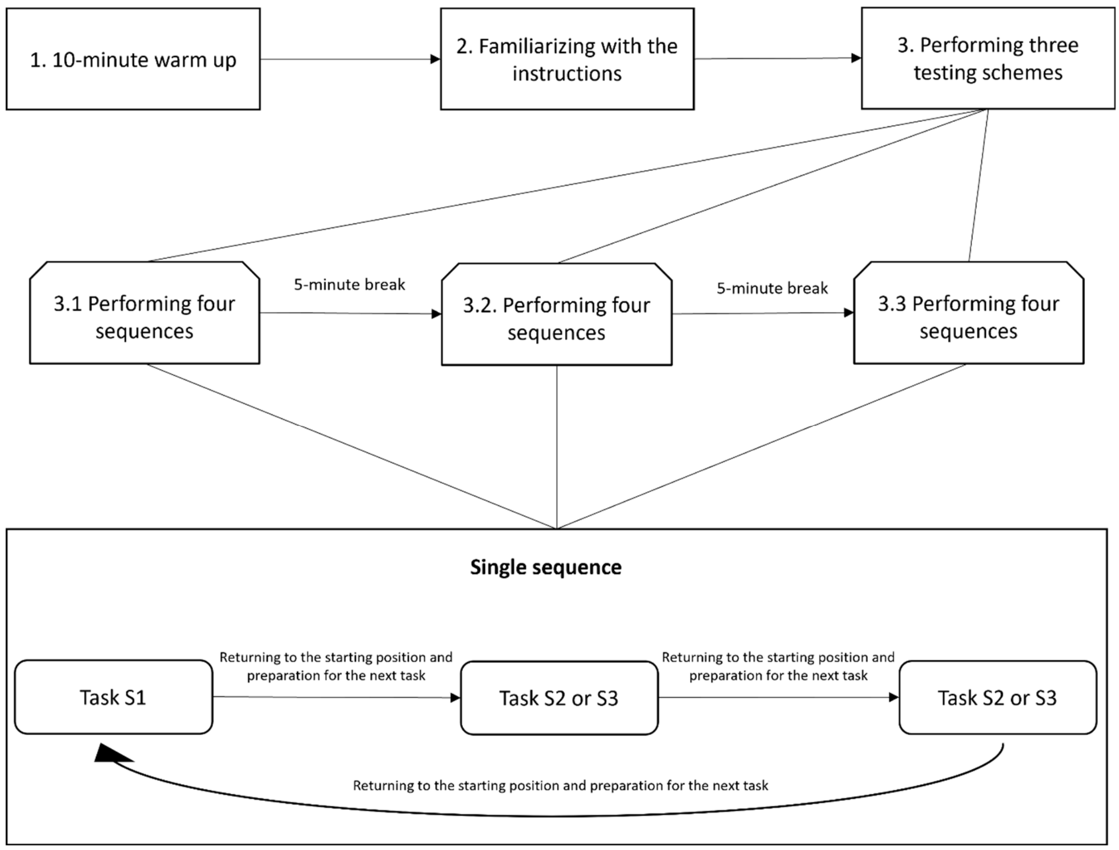

Figure 2. Diagram of the research procedure.

The deactivation of subsequent discs and time recording occurred when the athlete was within a maximum of 80 cm from the sensor. The time was analyzed in three measurements on the right and left sides: intermediate time (TI)—discs (3) and (4), respectively; time of movement to the jumping point (TJP)—discs (5) and (6), respectively; and total time (TT)—discs (7) and (8), respectively. Three light signals were established to condition the performance of tasks with varying difficulty.

Task (S1): Response to the light signal on the side of the player. All discs lit up in blue in front of the athlete on their right (3), (5), (7) or left (4), (6), (8). The player's task was to move from the starting position and complete the action by jumping to the block on the side where the light signal appeared. A detailed diagram of the player's behavior in response to the S1 light signal is presented in Figure 3.

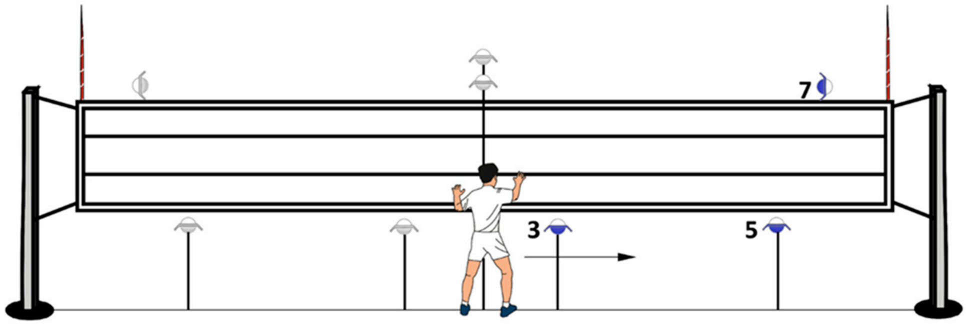

Figure 3. Diagram of the player's behavior in response to the S1 light signal.

Task (S2): Response to the light signal of the top disc or lower disc installed vertically over the net. The lower disc (1) or the top disc (2) lit up in blue in front of the player. When the lower disc (1) lit up, the participant performed a block to the right from the starting position; when the top disc (2) lit up, they performed a block to the left. A detailed diagram of the player's behavior in response to the S2 light signal is presented in Figure 4.

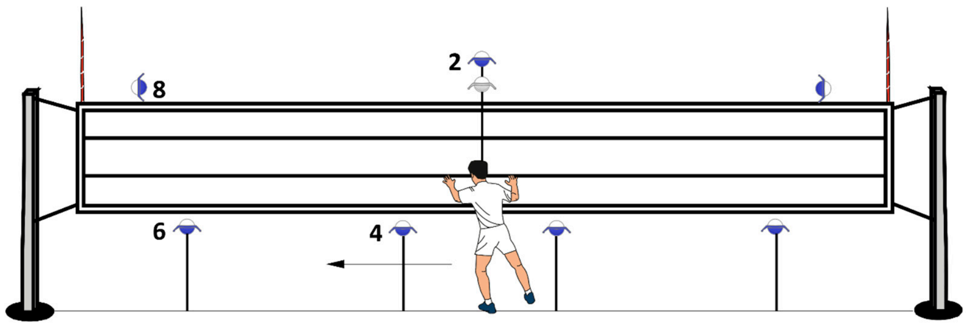

Figure 4. Diagram of the player's behavior in response to the S2 light signal.

Task (S3): Response to the color of the light signal of the top disc or lower disc installed vertically over the net. The lower disc (1) lit up in red, or the top disc (2) lit up in green in front of the player. When the red disc lit up, the participant performed a block to the left from the starting position, whereas, when the green disc lit up, they performed a block to the right. A detailed diagram of the player's behavior in response to the S3 light signal is presented in Figure 5.

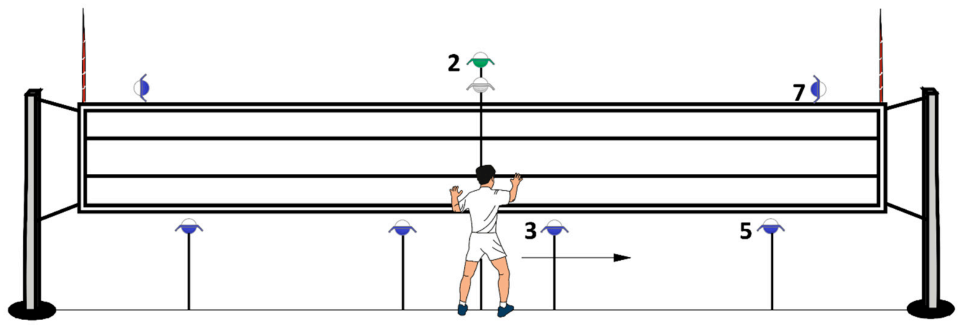

Figure 5. Diagram of the player's behavior in response to the S3 light signal.

A single sequence included the following.

(I). Task S1: The task started each sequence. The maximum performance time was 10 s. After the task was completed, the participant returned to the starting position in the centerline of the court at the net within 5 s and prepared for the next task. After this time, the next task began.

(II). Task S2 or S3: The competitor was not informed which type of signal would be displayed. The maximum time to complete the task including the return to the starting position was 10 s. After this time, the discs from the side opposite to the task performed were automatically switched off, and the participant prepared for the next task. After 3 s, the next task began.

(III). Task S2 or S3: In this case, the player was also not informed about the stimulus that would be displayed. The maximum time to complete the task, including the return to the starting position, was 10 s. After this time, the discs from the opposite side to the task performed were automatically switched off, and the participant prepared for the next task. After 3 s, the next task began.

In the implementation of the project, five schemes were prepared, based on the rule that each task (S1, S2, S3) was repeated twelve times (six times to the left and six times to the right side of the court). Participants were not informed of the order in which the tasks were to be performed.

2.3. Statistical Analysis

Statistical analysis was performed using the STATISTICA 13.1 software. The statistical significance level was set at $p \leq 0.05$. The normality of distribution was verified using the Shapiro–Wilk test. The Kruskal–Wallis test was used to evaluate the significance of time differences in the measurement of intermediate time (TI), time of movement to the jumping point (TJP), and total time (TT) in tasks S1, S2, and S3 performed in the same direction. Using a post hoc test, statistically significant differences were found between tasks (S1, S2, and S3) within each measurement (TI, TPJ, and TT).

3. Results

Table 1 shows descriptive statistics for measurements taken at the intermediate time (TI), time of movement to the jumping point (TJP), and total time (TT) for tasks S1, S2, and S3 performed to the left. Furthermore, Table 2 shows the differences in the performance time of tasks S1, S2, and S3 for TI, TPJ, and TT measurements. The largest differences in average performance time were found when comparing S1 to the other two tasks. In all three measurements, the differences in the times obtained in tasks S1 and S2 and tasks S1 and S3 were statistically significant in favor of task S1 ($p \leq 0.001$). A comparison of the performance times of tasks S2 and S3 showed statistical significance only in the TJP measurement in favor of task S3.

Table 1. Descriptive statistics for the measurements of intermediate time (TI), time of movement to the jumping point (TJP), and total time (TT) obtained in tasks S1, S2, and S3 for the test performed to the left.

Measurement	Task	M	SD	Me	Q1	Q3
TI [ms]	S1	607.38	128.01	622.00	522.00	670.00
	S2	986.60	417.04	895.00	1212.00	512.00
	S3	808.28	241.36	776.00	920.00	278.00
TJP [ms]	S1	2000.47	249.89	1970.00	1794.00	2174.00
	S2	2471.35	550.35	2343.00	2030.00	2742.00
	S3	2208.33	348.25	2102.00	1976.00	2427.00
TT [ms]	S1	2216.61	284.04	2128.00	2040.00	2316.00
	S2	2705.50	543.62	2529.00	2310.00	3022.00
	S3	2470.42	348.20	2364.00	2236.00	2662.00

Table 2. Significance of differences in performance time of tasks S1, S2, and S3 for measurements of intermediate time (IT), time of movement to the jumping point (MJT), and total time (TT) for the tasks performed to the left.

Measurement	Task	The Results (p) of the Comparison of Task Completion Time		
		S1	S2	S3
TI [ms]	S1	-	≤0.001	≤0.001
	S2	≤0.001	-	0.082
	S3	≤0.001	0.082	-
TJP [ms]	S1	-	≤0.001	≤0.001
	S2	≤0.001	-	≤0.05
	S3	≤0.001	≤0.05	-
TT [ms]	S1	-	≤0.001	≤0.001
	S2	≤0.001	-	0.053
	S3	≤0.001	0.053	-

Table 3 presents descriptive statistics for TI, TJP, and TT measurements in tasks S1, S2, and S3 performed to the right, whereas the significance of differences is presented in Table 4. Statistically significant differences ($p \leq 0.001$) in each measurement were observed between tasks S1 and S2 and tasks S1 and S3.

Table 3. Descriptive statistics for the measurements of intermediate time (TI), time of movement to the jumping point (TJP), and total time (TT) obtained in tasks S1, S2, and S3 for the test performed to the right.

Measurement	Task	M	SD	Me	Q1	Q3
TI [ms]	S1	669.56	166.81	652.00	586.00	694.00
	S2	949.42	501.79	794.00	652.00	977.00
	S3	944.15	323.32	891.00	378.00	2290.00
TJP [ms]	S1	1928.12	245.12	1866.00	1788.00	1978.00
	S2	2307.59	616.35	2080.00	1916.00	2580.00
	S3	2223.51	385.36	2136.00	1978.00	2362.00
TT [ms]	S1	2209.19	317.45	2158.00	2030.00	2324.00
	S2	2549.74	608.08	2339.00	2118.00	2838.00
	S3	2522.19	429.29	2434.00	2222.00	2676.00

Table 4. Significance of differences in performance time of tasks S1, S2, and S3 for measurements of intermediate time (IT), time of movement to the jump-off point (MJT), and total time (TT) for the tasks performed to the right.

Measurement	Task	The Results (p) of the Comparison of Task Completion Time		
		S1	S2	S3
TI [ms]	S1	-	≤0.001	≤0.001
	S2	≤0.001	-	0.184
	S3	≤0.001	0.184	-
TJP [ms]	S1	-	≤0.001	≤0.001
	S2	≤0.001	-	1.000
	S3	≤0.001	1.000	-
TT [ms]	S1	-	≤0.001	≤0.001
	S2	≤0.001	-	1.000
	S3	≤0.001	1.000	-

4. Discussion

The identification of the factors affecting blocking in volleyball seems to be one of the basic tasks to improve skills in this technical element. Furthermore, the cognitive skills of players [31] and their technical conditioning [32], affecting the way that they react to situations on the court, can contribute to greater success in competitive sports. The aim of the present study was to evaluate the time of moving in the block depending on the difficulty of the task determined by light signals. We hypothesized that increasing the difficulty of the task determined by the light signal would increase the movement time of the player in the block. This hypothesis was confirmed. In all measurements of intermediate time (TI), the players obtained significantly better time in task S1 than in tasks S2 and S3 ($p \leq 0.001$). Moreover, subsequent measurement of time of movement to the jumping point and total time (TPJ and TT) showed significantly better performance in task S1 ($p \leq 0.001$). A comparison of the times achieved in S2 and S3 showed only one statistically significant difference in favor of task S3 in TPJ for the tasks performed to the left ($p \leq 0.05$).

The analysis shows the great importance of the time required to evaluate visual signals for the movement of a player in a block. In all tests where significantly statistical differences were observed in the measurement of TI, such differences were also shown for the TPJ and TT measurements. This may indicate a significant impact of the time that it takes to recognize a signal and make a decision on the total movement time of a player in a block. The players moved much faster when the direction of movement was indicated by a disc placed on the same side (task S1). For tasks in which the direction of movement was determined by switching on an upper or lower (task S2) and green or red (task S3) disc, players needed considerably more time to make a move and move in the correct direction. The longer time in these tasks may also have been influenced by the additional task of having to recognize the displayed signals (S2 or S3).

As in the present study, one of the most commonly used devices to assess players' motor skills and cognitive processes is the FITLIGHT Trainer^{TM} [33–38]. The device finds its application both as a measurement tool and as a tool used in training to monitor the development of athletes in terms of specific motor parameters. Using the FITLIGHT Trainer^{TM}, studies have shown a beneficial effect of peripheral vision training in basketball, volleyball, and handball players in improving the time of manual reaction to visual stimuli [33]. Reaction speeds, agility, and dribbling skills were significantly improved in a group of youth basketball players after FITLIGHT reactive agility training [34]. However, in a similar study of young soccer players, no differences in the improvement in reaction time were observed between the control group and the group receiving FITLIGHT training [37]. There were also no statistically significant differences in improvements in executive function between the group playing basketball alone and the group receiving additional training with FITLIGHT [36].

In volleyball, the FITLIGHT Trainer^{TM} has been applied to control the skills of players moving in the block. However, to date, the problem of the effect of visual signals on the speed of movement in the block has not been exhaustively described in the literature. Previous studies have looked at moving in the block primarily in terms of assessing the effectiveness and speed of specific leg and hand techniques [10,11,13,14,16,39]. One study [14] used an arrangement of light discs near the net to recognize the different techniques of movement in the block and their effectiveness. In the present study, on the other hand, due to the adopted aim, the players were instructed to move using the slide step, which is the basic and simplest means of moving on the court. It is worth noting that in a study by [10], the action in the block was divided into different phases, showing that the fastest phases are the final phases, due to the translation of the run-up speed into jumping. Furthermore, it was shown that the players moved faster to their right, and the opposite hitters achieved a better total completion time than the middle blocker. In an attempt to explain this phenomenon, the authors point to the higher starting position of middle blockers, who must be prepared for different combinations of actions during the opponent's attack and movement to different zones of the court. In our study, with the group consisting of youth players, the specialization of players was not taken into account during the analysis. It seems that such a division should be applied to more advanced groups, as was the case in the aforementioned study [10]. The findings of the present study seem to demonstrate a legitimate need to assess the ability of players to quickly analyze and make decisions in response to various signals. Applied to training, learning how to respond to light signals can help athletes to improve their skill levels and increase the awareness of their abilities. Furthermore, it can provide information that, along with the physical parameters of the player, could indicate how to prepare him or her to specialize in playing in a specific position.

Few studies to date have focused on the effect of a player's laterality on their behavior when moving in different directions. The action of a player in a block does not end at the moment of successful or unsuccessful blocking of the ball and on the landing phase after the action. It was this phase of blocking that has been analyzed in other studies [15,40]. The authors focused on lower limb movements by comparing the behavior of the dominant and non-dominant limbs moving in the dominant and non-dominant directions. The results revealed different movement strategies both in situations where the lead limb was dominant or non-dominant and when comparing situations where both limbs performed the same roles [15]. Differences in strategies for planned and unplanned movements were also found. Planned movements, due to less focus on performing the movement than unplanned movements, can potentially cause more injuries [40]. In our study, a distinction was made between the results for left- and right-side tests. It would be interesting to conduct similar analyses taking into account the laterality of the players and the correct determination of dominant and non-dominant directions. In prior studies [15,40], the dominant direction of moving was to the left for right-legged athletes and to the right for those who were left-legged. For the authors, the deciding factor was the assignment of cross-over step movements in the block to the natural movements of the player in the attack (for those who were right-legged: left–right–left legs; for the left-legged: right–left–right legs). It would be necessary to consider how to determine the dominant and non-dominant sides in the case of other means of movement, as in the case of the slide step.

Evaluating the speed of movement of players in a block in response to different types of signals is an important and topical research objective. The research results presented here do not answer all the questions that arise from the problem discussed. In the study, we attempted to reflect match conditions by implementing the read-and-react strategy of blocking, which is an important part of the team's defensive play [5,8]. However, performing the procedure once does not allow for the assessment of the potential for improved performance using FITLIGHT Trainer™ training. With the increasing sports skill level, higher demands related to the number of combinations in the attack are placed on blockers [41]. It would therefore be interesting to implement a properly planned training process that could improve key skills to respond to various signals using ongoing control. Another objective for the development of this research would be the use of additional variables that could affect the analyzed results, such as allowing players to use other means of moving or determining other starting positions and distances covered by players who specialize in playing in different positions. Applying the division of movement into the dominant and non-dominant directions in the analysis could also become the basis for targeted training depending on the observed trends.

To the best of our knowledge, the present paper is the first to use such a procedure to assess movement in a block in response to light signals using modern FITLIGHT Trainer™ measuring devices. Nevertheless, despite the strengths of our study, our research also has some limitations that should be indicated. When comparing the findings of the present study to those presented by other authors, it is worth noting the use of slide step in the procedure of movement. Although some studies have indicated that this technique should be used primarily for shorter distances [11,39], it guaranteed that all athletes moved in the same way. Therefore, training experience was not an exclusion criterion for participation in the study. However, it can be assumed that for players who more often move using other techniques, imposing a different technique could affect the quality of the task performed. It also appears that the body height and the length of the upper and lower limbs can affect the number of steps needed during movement and the difference in time between take-off and positioning the block at the correct height. This means that shorter players may need more time to position the block properly. An important factor that was taken into account when preparing the study procedure was the proper planning of rests. The division of all tasks into three patterns consisting of four sequences allowed the players' susceptibility to fatigue resulting from motor activities and prolonged attention to be reduced. However, in the case of the rests between individual tasks in a single sequence, their full unification was impossible due to the limited capabilities of the FITLIGHT Trainer^{TM} system. The rest time between tasks S1 and S2 or S3 varied depending on the task performance speed. However, it was demonstrated that the FITLIGHT Trainer^{TM} system allows for the creation of conditions similar to those during a game.

Furthermore, we are aware that to conduct deeper analyses of the effects of training complex perceptual–cognitive skills on the improvement of specific motor skills used in volleyball, it would be necessary to design more detailed measurements and longitudinal studies. In addition, our study focused only on young men practicing volleyball, so it would be worthwhile to include measurements of young women and adult women and men with different levels of sports experience in future studies. Given the nature of the present study, the small group size, and the above weaknesses, we emphasize that our results should be interpreted with caution, and we are far from any generalizations.

Nevertheless, we believe that perceptual training designed to develop visual and perceptual–cognitive skills to achieve better training results in real-world competitions can help to improve athlete efficiency. Furthermore, the FITLIGHT Trainer^{TM} system, despite its limitations, can be a useful tool to conduct research in this field.

5. Conclusions

The results of the study show a significant effect of different light signals on the time of moving in the block. Indeed, players performed better on tasks with lower complexity compared to those that required the recognition of a more complex signal. In all phases of movement, the response to a signal required less time in task S1 compared to tasks S2 and S3. At the same time, no statistically significant differences in total task completion time were observed between S2 and S3. The results obtained in the study can be used to further analyze the phenomena of performing actions in response to various visual cues.

The results of the study showed that the complexity of the visual signal can affect the time of a player's moving in a block. The presented research procedure can be used both as a form of evaluation of the current skills of the players and as a form of improving the skills of "reading" the game in the block. Depending on the skill level of the players' group, it is possible to adjust the arrangement of the discs to meet training needs. The advantage of the FITLIGHT Trainer^{TM} system is that it can be used with an intuitive smartphone app, making it not only a tool for sport-specific testing but also a device for everyday use for sports training.

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