Original Article

Level of psychomotor abilities and handball goalkeepers' actions during throws in fast break

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Abstract

The aim of the study was to determine whether the level of psychomotor abilities differentiates the actions of handball goalkeepers, and to indicate the strength and type of the relationship between the level of selected psychomotor abilities and the activities of goalkeepers during saves in a fast break. The research included ten leading goalkeepers of the Polish PGNiG Superleague. The research material was video recordings of goalkeeper saves during fast attack throws ($n = 386$). To assess goalkeepers' actions, the observation method categorized according to Norkowski's concept was used. The level of selected psychomotor abilities was assessed using the Vienna Test System. RT test (ver.S.1)-simple reaction time, RT test (ver.S.3)-reaction time with choice; ZBA test (ver.S.3)-time-space anticipation. The statistical tests used were the Mann-Whitney U Test, Spearman's Rho, and regression analysis. The results indicate that the level of psychomotor abilities does differentiate the actions of goalkeepers. Goalkeepers with lower level of simple reaction times have more fast-paced save after a delay ($p < 0.05$). Players with lower level of reaction time with choice have more save in wrong direction, right high ($p < 0.05$). Goalkeepers with lower level of time anticipation have more save without reducing the defensive area within the stance ($p < 0.05$), and earlier moment of the initiation of the save ($p < 0.05$). In goalkeepers with lower level of median direction deviation is more save after reducing the defensive area within the stance ($p < 0.05$), and in players with higher level of median direction deviation is more save after reducing the defensive area with a step out/dive ($p < 0.05$). There is a correlation between motor time (RT test ver.S.1.) and a successful effect of the save ($r_s = 0.73$, $p < 0.05$). The level of time anticipation [ZBA] was indicated as a predictor of earlier initiation of the save ($F_{(1,8)} = 14.070$, $p = 0.00562$, $SE = 3.84\%$, $R^2 = 0.6375$). The level of motor time (RT test ver.S.1.) was indicated as a predictor of optimal range of goalkeepers' movement relative to the ball's path ($F_{(1,8)} = 11.228$, $p = 0.01007$, $SE = 9.97\%$, $R^2 = 0.5839$). The level of motor time (RT test ver.S.1.) and median direction deviation [ZBA] was indicated as a predictor of too small range of goalkeepers movement relative to the ball's path ($F_{(2,7)} = 17.576$, $p = 0.00187$, $SE = 4.81\%$, $R^2 = 0.8339$). The results indicate that a lower level of psychomotor abilities, in terms of reaction time, motor time, space-time anticipation determines a higher quality of goalkeeper actions.

Key words: reaction time, motor time, anticipation, regression, performance, analysis

Introduction

A players' ability to anticipate the movement of both the opponent and the ball, as well as the appropriate choice of reaction, cognitive efficiency, and a high level of motor fitness, significantly affect sporting success. (Paul et al., 2012; Kioumourtzoglou et al., 1998). Research suggests that the combination of the ability to perceive, anticipate, and divide attention has an impact on the outcome of team sports (Mankowska et al., 2015). Participation in sports competitions is associated with the need to play sports in venues at different times and locations, which is why focus, anticipation, prediction of opponent's movements, and fast movement on the field are important aspects of sport (Paul et al., 2012). On this basis, it can be concluded that psychomotor abilities, including reaction time, may have an impact on sports performance and success (Yüksel&Tunç 2018; Paul et al., 2012; GURSOY et al., 2012; KIDA et al., 2005; ABBOTT et al., 2005). Studies demonstrate that the reaction time is shorter among more professional players than in others, and that apart from technical and tactical preparation-it also has an impact on the chances of victory (Yüksel&Tunç 2018). The literature also includes publications which reveal that one's reaction time and anticipation depend on the level of training (Simonet et al., 2019; Maghsoudipour et al., 2018). In addition, there are also articles which describe research on simple reaction time to visual stimuli which takes into account the dominant and non-dominant hand in groups of athletes from various sports (Badau et al., 2018). Psychomotor abilities are also a subject of handball research. A review of the literature shows differences in reaction time (arm and leg) between teams ranking high and low in the tournament. There are also differences in this parameter before and after the match (Menevse&Arslan, 2012). Current research also points to differences in the level of psychomotor abilities depending on the handball players' gender, age, and position in the game (Kiss&Balogh, 2019). Some publications suggest that with age,

sports experience and professional sport level, players' reaction time shortens (Przednówek et al., 2019; Biscaia et al., 2018). Research to date also reveals that more exercise leads to a reduction in cognitive processing time, particularly in the situation of many complex stimuli (Biscaia et al., 2018). In addition to reaction time studies, the literature also indicates differences in the level of anticipation depending on age, professional experience (Biscaia et al., 2018), gender, and the tactical situation of the throw (Ilia et al., 2015).

Articles on the subject do not only examine the psychomotor abilities of handball players overall, but also focus their analysis on goalkeepers alone. Research demonstrates a high level of reaction time and motor time in tests of simple reaction time tests and reaction time with choice tests, and an average level of anticipation of time and space (Przednówek et al., 2019, Krawczyk et al., 2018). The research by Krawczyk et al. (2019) also shows differences in the number of defences after reducing the defensive area with a step out/dive depending on the level of simple reaction time in the situation of a throw from the wing position and also shows a trend in fast-paced saves after a delay when throws are performed from the wing position depending on the level of anticipation of direction Helm et al. (2016) have proven that goalkeepers at a higher professional level have a shorter reaction time to both specific and non-specific stimuli. The literature also points to differences in the reaction time of goalkeepers depending on the quality of sleep (Jarraya et al., 2012). Apart from the studies on reaction time, it is also necessary to mention the publications which focus on the analysis of anticipation of handball goalkeepers in the situation of direct throws at the goal. Biscaia et al. (2018) and Rojas et al. (2012) show a higher level of anticipation of goalkeepers depending on professional experience. Previous reports indicate a difference in goalkeepers' anticipation depending on gender, position of the throw, and the tactical situation of the throw (i.e., penalty throws, one-on-one) (Ilia et al., 2015). Loffing and Hageman (2014), in analyzing the anticipation of goalkeepers in penalty throws, conclude that experienced goalkeepers use many stimuli when making decisions in anticipation (the throwing arm, the upper body, the kinematic characteristics of the thrower). Alsharjani and Wade (2015) indicate that as a result of perceptive training, goalkeepers have improved their anticipation in penalty throw situations. The same authors also point to a higher level of anticipation of direct throws than those preceded by a feint.

In addition to the investigation of the psychomotor abilities of handball goalkeepers, an important element of research is also the analysis of the game and the search for factors that affect success in sports. Hansen et al. (2017) indicates a strong relationship between the effectiveness of a goalkeepers' save and where the team places in the World Championship. Daza et al. (2017) suggest that the effectiveness of the goalkeeper's saves is one of the factors differentiating the result of a match (win/lose) at a high-ranking tournament (World Championship). Krawczyk et al. (2020) indicate differences in the handball goalkeepers' actions depending on the contact of the throwing player with the defender. The literature also indicates that the number of fast breaks made by the team determines the outcome of the match (Molfetas et al., 2019; Bojgoric et al., 2017). One of the goalkeepers' actions during a handball match is to defend throws in a fast break. Sliz and Dziadek (2017) indicate a decrease in the effectiveness of goalkeepers' defenses in the situation of fast break throws at the European Championships over the last 16 years. The research to date also suggests that at high-level tournaments (Olympic Games), the effectiveness of throw defenses in a fast attack differentiated the outcome (win/lose) (Saavedra et al., 2017). The current analysis of handball goalkeepers' game mainly focuses on the effect of the save (effective/ineffective). Hatzimanouil (2019) states that an analysis of the goalkeepers' play which is based only on recording the effectiveness of the defense is insufficient, as it does not provide the opportunity to learn about the factors of effective actions of goalkeepers, or to learn about the objective reasons for the lack of effectiveness of the game in this player position. Norkowski (1996, 1997) indicates that a goalkeeper's save is a series of motor-mental operations, and the effect of the save is only the last sequence of a series of actions in the entire process. It is therefore necessary to undertake a comprehensive analysis of the goalkeeper's play to reasons for ineffective saves, which will have a specific and practical bearing on optimizing the training process.

In connection with the presented results aim of the study was to determine whether the level of psychomotor abilities differentiates the actions of handball goalkeepers, and to indicate the strength and direction of the relationship between the level of selected psychomotor abilities and the activities of goalkeepers during saves in a fast break.

Methods

Participants

The research covered all basic goalkeepers at the highest professional level ($n = 10$: National Team $n = 3$; Superleague $n = 7$) who played in the Polish PGNiG Men's Superleague in the 2015–16 season. The average age of the respondents was 30.45 ± 5.45 years, and their professional experience was 19.82 ± 5.55 years.

Measurements

The research material was a video recording (88 matches) of goalkeeper saves during fast break throws ($n = 386$) in top-class matches in Poland (PGNiG Men's Superleague) during the 2015–16 season. Inaccurate throws and those in which the thrower was fouled and the referee stopped the game were not included in the study. The video recording complies with the guidelines of the Handball Association in Poland.

To assess goalkeepers' actions, the observation method categorized according to Norkowski's concept (1997, 1996) (Krawczyk et al. 2019, 2020) was used. The following goalkeepers' actions were registered: type of

save (after reducing the defensive area within the stance, after reducing the defensive area with a step out/dive, without reducing the defensive area within the stance, without reducing the defensive area with a step out/dive), the moment of initiating the save (earlier (anticipation), fast-paced save after a delay, late), the accuracy of the goalkeeper's movement relative to the ball's trajectory (correct direction and height, correct direction, wrong height, wrong direction, correct height, wrong direction and height), range of goalkeeper's movement relative to the ball's trajectory (optimal, too small, too wide), save technique (correct, inadequate), effect of the save (unsuccessful (goal), successful (defended throw)). The level of psychomotor abilities was assessed using the Vienna Test System. RT test version S.1 was used to measure simple reaction time [SRT] and RT test version S.3 was used to measure the reaction time with choice [CRT]. The following variables were recorded: reaction time and motor time. ZBA test version S.3 was used in the linear form to measure time-space anticipation. The recorded parameters were the median time deviation and the median direction deviation. Psychomotor abilities were tested in the starting season, prior to the third training unit of the starting microcycle on the dominant upper limb. The measurements were preceded by a specialized 15-minute goalkeeper warm-up. The classification of the players into groups with higher and lower levels of psychomotor abilities was made using the median for the results of the tests. The median for individual tests on the Vienna Test System was as follows: reaction time [SRT] – 199.5 ms, motor time [SRT] – 84.5 ms, reaction time [CRT] – 297 ms, motor time [CRT] – 80 ms, median deviation time [ZBA] – 0.675 sec, and median direction deviation [ZBA] – 17.5 pixels.

Statistical analysis The gathered data was subjected to statistical analysis. We calculated the basic statistical characteristics: mean, standard deviation, and percentage. The median for the entire data set was used to divide the goalkeepers into groups with a higher and lower level of psychomotor abilities. Due to the qualitative nature of the data, nonparametric statistics were used. The Mann–Whitney U test was used for comparisons between groups. Spearman's Rho was used to establish the correlation between the variables. The analysis of the impact of the level of psychomotor abilities on the actions of goalkeepers was determined using multiple (stepwise-backward) regression. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using Statistica and Microsoft Office Excel software.

Results

The data on goalkeepers' actions depending on the level of simple reaction time and motor time [SRT] are presented in Table 1. Data analysis indicates a higher percentage of fast-paced saves after a delay for goalkeepers with a lower reaction time (8.05%) compared to the subjects with a higher level of the given ability (3.08%). The difference is statistically significant ($Z = -2.29783$, $p < 0.05$). There are no statistically significant differences in any actions of goalkeepers analyzed in the study depending on the level of motor time.

Table 1. Reaction time and motor time in test SRT and a goalkeepers' actions

Goalkeepers' actions	HLRT	LLRT	P-value	HLMT	LLMT	P-value
	192.4 ± 4.16 [ms]	211.8 ± 14.7 [ms]		70.4 ± 9.81 [ms]	88.6 ± 3.05 [ms]	
	Mean ± SD [%]	Mean ± SD [%]		Mean ± SD [%]	Mean ± SD [%]	
Type of save						
after reducing the defensive area within the stance	92.63 ± 4.63	89.39 ± 2.93	ns	91.66 ± 5.58	90.36 ± 2.09	ns
after reducing the defensive area with a step out/dive	3.17 ± 3.36	5.78 ± 4.73	ns	3.47 ± 3.69	5.49 ± 4.67	ns
without reducing the defensive area within the stance	2.70 ± 1.72	3.78 ± 2.60	ns	2.90 ± 1.92	3.18 ± 2.50	ns
without reducing the defensive area with a step out/dive	1.49 ± 1.37	1.45 ± 2.17	ns	1.97 ± 1.11	0.98 ± 2.18	ns
The moment of the initiation of the save						
earlier (anticipation)	80.83 ± 6.50	81.54 ± 6.23	ns	81.45 ± 5.99	80.92 ± 6.73	ns
fast-paced save after a delay	3.08 ± 2.17	8.05 ± 1.79	$p < 0.05$	3.85 ± 3.57	7.28 ± 1.83	ns
late	14.89 ± 7.31	11.39 ± 6.45	ns	14.70 ± 7.39	11.58 ± 6.48	ns
The accuracy of the goalkeeper's movement relative to the ball's trajectory						
correct direction and height	44.29 ± 10.21	38.69 ± 4.07	ns	41.82 ± 9.05	41.16 ± 7.62	ns
correct direction, wrong height	19.53 ± 10.08	19.15 ± 6.25	ns	19.65 ± 9.96	19.03 ± 6.42	ns
wrong direction, right height	5.32 ± 5.19	7.85 ± 5.61	ns	5.52 ± 5.14	7.65 ± 5.76	ns
wrong direction and height	30.85 ± 7.42	34.31 ± 5.70	ns	33.01 ± 9.22	32.15 ± 3.11	ns
Range of goalkeeper's movement relative to the ball's trajectory						
optimal	72.75 ± 19.33	73.91 ± 10.18	ns	68.71 ± 20.22	77.95 ± 4.00	ns
too small	17.11 ± 11.92	19.57 ± 9.88	ns	20.86 ± 14.53	15.82 ± 4.07	ns
too wide	10.14 ± 8.59	6.50 ± 5.04	ns	10.43 ± 8.42	6.21 ± 5.03	ns

Save technique						
correct	74.05 ± 7.26	80.83 ± 9.43	ns	73.34 ± 7.02	81.54 ± 8.88	ns
inadequate	25.95 ± 7.26	19.17 ± 9.43	ns	26.66 ± 7.02	18.46 ± 8.88	ns
Effect of the save						
unsuccessful (goal)	81.19 ± 3.91	78.69 ± 4.79	ns	82.39 ± 3.31	77.50 ± 4.02	ns
successful (defended throw)	18.80 ± 3.91	21.31 ± 4.79	ns	17.61 ± 3.31	22.50 ± 4.02	ns

HLRT=Higher Level of Reaction Time (n=191), LLRT=Lower Level of Reaction Time (n=195), HLMT=Higher Level of Motor Time (n=180), LLMT=Lower Level of Motor Time (n=206), SD=Standard Deviation, ms=millisecond, ns=no significant

Table 2 shows the effects of goalkeepers' actions depending on the level of reaction time and motor time [CRT]. The analysis of our results indicates statistically significant differences ($Z=-2.29783$, $p<0.05$) in the "accuracy of the goalkeeper's movement" (wrong direction, correct height) depending on the level of reaction time (higher: 2.62%, lower: 10.55%). The data presented in Table 2 reveal the difference (on the borderline of the adopted level of significance) in fast-paced saves after a delay for goalkeepers with a higher (3.65%) and lower (7.48%) level of reactiontime with choice ($Z=-1.88004$, $p=0.06$). Analysis of the data on the level of motor time [CRT] does not differentiate the actions of goalkeepers in the situation of throws in a fast break.

Table 2. Reaction time and motor time in test CRT and a goalkeepers' actions

Goalkeepers' actions	HLRT 276.2 ± 12.70 [ms] Mean ± SD [%]	LLRT 317 ± 23.58 [ms] Mean ± SD [%]	p-value	HLMT 63.6 ± 13.54 [ms] Mean ± SD [%]	LLMT 92 ± 10.86 [ms] Mean ± SD [%]	p-value
Type of save						
after reducing the defensive area within the stance	92.58 ± 4.64	89.43 ± 2.97	ns	91.66 ± 5.58	90.36 ± 2.09	ns
after reducing the defensive area with a step out/dive	3.74 ± 3.50	5.21 ± 4.93	ns	3.47 ± 3.69	5.49 ± 4.67	ns
without reducing the defensive area within the stance	2.72 ± 1.72	3.36 ± 2.60	ns	2.90 ± 1.92	3.18 ± 2.50	ns
without reducing the defensive area with a step out/dive	0.94 ± 1.31	1.99 ± 2.06	ns	1.97 ± 1.11	0.98 ± 2.18	ns
The moment of the initiation of the save						
earlier (anticipation)	81.85 ± 7.42	80.52 ± 5.02	ns	81.45 ± 5.99	80.92 ± 6.73	ns
fast-paced save after a delay	3.65 ± 2.40	7.48 ± 2.90	$p=0.06$	3.85 ± 3.56	7.28 ± 1.83	ns
late	13.30 ± 8.46	12.98 ± 5.57	ns	14.70 ± 7.39	11.58 ± 6.48	ns
The accuracy of the goalkeeper's movement relative to the ball's trajectory						
correct direction and height	41.27 ± 7.46	41.71 ± 9.20	ns	41.82 ± 9.05	41.16 ± 7.62	ns
correct direction, wrong height	22.37 ± 8.94	16.31 ± 6.15	ns	19.65 ± 9.96	19.03 ± 6.42	ns
wrong direction, right height	2.62 ± 2.86	10.55 ± 3.86	$p<0.05$	5.52 ± 5.14	7.65 ± 5.76	ns
wrong direction and height	33.74 ± 3.27	31.43 ± 9.00	ns	33.01 ± 9.22	32.15 ± 3.11	ns
Range of goalkeeper's movement relative to the ball's trajectory						
optimal	79.65 ± 12.22	67.01 ± 15.13	ns	68.71 ± 20.22	77.95 ± 4.00	ns
too small	14.51 ± 8.74	22.17 ± 11.42	ns	20.86 ± 14.53	15.82 ± 4.07	ns
too wide	5.81 ± 6.56	10.83 ± 6.97	ns	10.43 ± 8.42	6.21 ± 5.03	ns
Save technique						
correct	78.88 ± 11.13	75.97 ± 6.42	ns	73.34 ± 7.02	81.54 ± 8.88	ns
inadequate	21.12 ± 11.13	24.03 ± 6.42	ns	26.66 ± 7.02	18.46 ± 8.88	ns
Effect of the save						
unsuccessful (goal)	78.34 ± 4.27	81.54 ± 4.18	ns	82.39 ± 3.31	77.50 ± 4.02	ns
successful (defended throw)	21.66 ± 4.27	18.46 ± 4.18	ns	17.61 ± 3.31	22.50 ± 4.02	ns

HLRT=Higher Level of Reaction Time (n=190), LLRT=Lower Level of Reaction Time (n=196), HLMT=Higher Level of Motor Time (n=180), LLMT=Lower Level of Motor Time (n=206), SD=Standard Deviation, ms=millisecond, ns=no significant

Table 3 demonstrates the results regarding goalkeepers' actions depending on the level of anticipation of time and place in the ZBA test. The analysis of the results indicates statistically significant differences ($Z=2.08893$, $p<0.05$) in the number of saves "without reducing the defensive area within the stance", depending on the level of anticipation of time: higher (1.74%), and lower (4.34%). For the analyzed parameter, there are also differences ($Z=2.29783$, $p<0.05$) in the percentage of "earlier" defenses: higher (76.92%) and lower

(85.67%). We must also note a higher percentage of “late” saves in goalkeepers with a higher level of anticipation (17.80%) than with a lower level (8.48%), whose statistical significance ($Z=1.88004$, $p=0.06$) is on the borderline of the threshold for significance. Analysis of the data presented in Table 3 also indicates the differences ($Z=2.50672$, $p<0.05$) in the percentage of saves after reducing the defensive area within the stance of goalkeepers with higher (88.13%) and lower (93.88%) levels of anticipation of direction [ZBA]. The percentage of saves after reducing the defensive area with a step out/dive also differs statistically ($Z=-2.29783$, $p<0.05$) in subjects with a higher (7.30%) and lower (1.65%) level of anticipation of direction [ZBA].

Table 3. Time and space anticipation in test ZBA and a goalkeepers' actions

Goalkeepers' actions	HLTA	LLTA	p-value	HLMDD	LLMDD	p-value
	0.50 ± 0.12	0.99 ± 0.17		14.60 ± 1.82	31.80 ± 11.43	
	[s]	[s]		[pixels]	[pixels]	
	Mean ± SD [%]	Mean ± SD [%]		Mean ± SD [%]	Mean ± SD [%]	
Type of save						
after reducing the defensive area within the stance	91.60 ± 5.21	90.42 ± 2.92	ns	88.13 ± 1.96	93.88 ± 3.47	$p<0.05$
after reducing the defensive area with a step out/dive	5.19 ± 5.40	3.77 ± 2.74	ns	7.30 ± 3.44	1.65 ± 2.48	$p<0.05$
without reducing the defensive area within the stance	1.74 ± 1.68	4.34 ± 1.72	$p<0.05$	3.59 ± 2.57	2.49 ± 1.62	ns
without reducing the defensive area with a step out/dive	1.48 ± 2.19	1.47 ± 1.35	ns	0.98 ± 1.34	1.97 ± 2.05	ns
The moment of the initiation of the save						
earlier (anticipation)	76.92 ± 2.82	85.67 ± 4.80	$p<0.05$	79.72 ± 4.11	82.64 ± 7.69	ns
fast-paced save after a delay	5.29 ± 4.07	5.85 ± 2.56	ns	6.62 ± 2.74	4.51 ± 3.61	ns
late	17.80 ± 5.71	8.48 ± 3.98	$p=0.06$	12.46 ± 4.78	13.82 ± 8.87	ns
The accuracy of the goalkeeper's movement relative to the ball's trajectory						
correct direction and height	40.80 ± 8.02	42.19 ± 8.65	ns	41.13 ± 7.65	41.85 ± 9.02	ns
correct direction, wrong height	21.83 ± 9.07	16.85 ± 6.54	ns	16.00 ± 5.84	22.67 ± 8.88	ns
wrong direction, right height	5.40 ± 4.90	7.78 ± 5.91	ns	6.67 ± 4.57	6.51 ± 6.45	ns
wrong direction and height	31.97 ± 4.12	33.19 ± 8.79	ns	36.19 ± 4.20	28.97 ± 6.70	ns
Range of goalkeeper's movement relative to the ball's trajectory						
optimal	81.38 ± 11.37	65.28 ± 13.67	ns	70.70 ± 8.16	75.96 ± 19.86	ns
too small	13.68 ± 8.96	23.00 ± 10.43	ns	21.63 ± 8.49	15.05 ± 12.02	ns
too wide	4.95 ± 3.07	11.69 ± 8.34	ns	7.67 ± 3.65	8.97 ± 9.64	ns
Save technique						
correct	77.89 ± 5.19	76.98 ± 11.95	ns	77.33 ± 5.46	77.55 ± 11.85	ns
inadequate	22.11 ± 5.19	23.02 ± 11.95	ns	22.67 ± 5.46	22.45 ± 11.85	ns
Effect of the save						
unsuccessful (goal)	80.16 ± 3.42	79.72 ± 5.51	ns	81.10 ± 2.63	78.79 ± 5.65	ns
successful (defended throw)	19.84 ± 3.42	20.28 ± 5.51	ns	18.90 ± 2.63	21.21 ± 5.56	ns

HLTA=Higher Level of Time Anticipation (n=198), LLTA=Lower Level of Time Anticipation (n=188), HLMDD=Higher Level of Median Direction Deviation (n=211), LLMDD=Lower Level of Median Direction Deviation (n=175), SD=Standard Deviation, ns=no significant

The results of the correlation between the level of psychomotor abilities and the actions of goalkeepers during a save are demonstrated in Table 4. Analyzing the type of save, it is clear that the strongest relationships were recorded between saves after reducing the defensive area within the stance ($r_s=0.91$, $p<0.05$) and after reducing the defensive area with a step out/dive ($r_s=-0.90$, $p<0.05$), and the median direction deviation in the anticipation test [ZBA]. Slightly weaker relationships were observed between the level of psychomotor abilities and the moment of the initiation of the save. A very high correlation was found between reaction time [SRT] and the percentage of fast-paced saves after a delay ($r_s=0.77$, $p<0.05$). Test results also showed a high correlation between reaction time [CRT] and the moment of starting a fast-paced save after a delay ($r_s=0.66$, $p<0.05$). The “earlier” initiation of the save was strongly correlated ($r_s=0.70$, $p<0.05$) with time anticipation in the ZBA test. A high correlation was revealed in the accuracy of the goalkeeper's movement relative to the ball's path ($r_s=0.67$, $p<0.05$) between the “wrong direction and correct height” of the save and the reaction time [CRT]. The “optimal” range of the goalkeeper's movement relative to the ball's path is highly correlated ($r_s=0.78$, $p<0.05$) with motor time [SRT]. Analyzing the save techniques of goalkeepers, it should be stated that there is a high correlation between “correct” ($r_s=0.68$, $p<0.05$) and “inadequate” ($r_s=-0.67$, $p<0.05$) technique and motor time [SRT]. The data in Table 4 also indicate a strong relationship ($r_s=0.67$, $p<0.05$) between “correct” and

“inadequate” ($r_s = -0.67$, $p < 0.05$) save techniques with the level of motor time [CRT]. Analysis of the effects of goalkeepers’ saves leads to the conclusion that it is very highly correlated with motor time [SRT] (unsuccessful $r_s = -0.73$, $p < 0.05$; successful $r_s = 0.73$, $p < 0.05$).

Table 4. Correlations between level of psychomotor abilities and goalkeepers’ actions

Goalkeepers’ actions	RTSRT	MTSRT	RTCRT	MTCRT	TAZBA	MDDZBA
Type of save						
after reducing the defensive area within the stance	-0.46	0.10	-0.30	-0.18	0.19	0.91*
after reducing the defensive area with a step out/dive	0.22	-0.06	0.15	0.10	-0.33	-0.90*
without reducing the defensive area within the stance	0.47	-0.15	-0.08	0.19	0.55	-0.01
without reducing the defensive area with a step out/dive	-0.40	-0.32	0.19	-0.51	0.06	0.27
The moment of the initiation of the save						
earlier (anticipation)	0.22	-0.39	0.05	-0.09	0.70*	0.27
fast-paced save after a delay	0.77*	0.42	0.66*	0.49	0.14	-0.47
late	-0.52	0.05	-0.12	-0.17	-0.62	0.04
The accuracy of the goalkeeper’s movement relative to the ball’s trajectory						
correct direction and height	-0.38	0.02	-0.05	0.05	0.18	0.07
correct direction, wrong height	0.04	0.24	-0.20	0.00	-0.26	0.07
wrong direction, right height	0.29	-0.07	0.67*	0.11	0.30	0.09
wrong direction and height	0.29	-0.31	-0.31	-0.22	-0.14	-0.47
Range of goalkeeper’s movement relative to the ball’s trajectory						
optimal	0.13	0.78*	-0.18	0.50	-0.25	0.09
too small	0.04	-0.52	0.27	-0.17	0.22	-0.44
too wide	-0.25	-0.46	0.11	-0.42	0.31	0.39
Save technique						
correct	0.24	0.68*	-0.16	0.67*	0.05	-0.09
inadequate	-0.24	-0.68*	0.16	-0.67*	-0.05	0.09
Effect of the save						
unsuccessful (goal)	-0.18	-0.73*	0.31	-0.43	-0.25	-0.30
successful (defended throw)	0.18	0.73*	-0.31	0.43	0.25	0.30

RTSRT=Reaction Time in test SRT, MTSRT=Motor Time in test SRT, RTCRT=Reaction Time in test CRT, MTCRT=Motor Time in test DT, TAZBA=Time Anticipation in test ZBA, MDDZBA= Median Direction Deviation in test ZBA, *= $p < 0.05$

Statistical regression analysis allowed us to explore three statistically significant models, and indicate the level of psychomotor abilities as predictors of handball goalkeepers’ actions in a fast break situation.

The first model concerns the “earlier” initiation of the save (Y):

$$Y = 16.37008x_{\text{time anticipation [ZBA]}} + 69.05118$$

In order to estimate the impact of the level of psychomotor abilities [SRT, CRT, and ZBA] on the “earlier” initiation of the save by handball goalkeepers, we used regression analysis. The model turned out to be significant ($F_{(1,8)} = 14.070$, $p = 0.00562$, $SE = 3.84\%$), and the predictors obtained through it explained 63.75% of the dependent variable ($R^2 = 0.6375$). The level of anticipation of time [ZBA] had a significant impact on the “earlier” initiation of the save by goalkeepers ($\beta = 16.37008$, $p = 0.005616$).

The second model concerns the “optimal” range of goalkeepers’ movement relative to the ball’s path (Y):

$$Y = 0.9452x_{\text{motor time [SRT]}} - 1.81323$$

In order to estimate the impact of psychomotor abilities [SRT, CRT, and ZBA] on the “optimal” range of goalkeepers’ movement in relation to the ball flight path, we used regression analysis. The model turned out to be significant ($F_{(1,8)} = 11.228$, $p = 0.01007$, $SE = 9.97\%$), and the predictors obtained through it explained 58.39% of the dependent variable ($R^2 = 0.5839$). The level of reaction time [SRT] had a significant impact on the goalkeepers’ “optimal” range of movement ($\beta = 0.9452$, $p = 0.010069$).

The third model concerns the “too small” range of goalkeepers’ movement relative to the ball’s path (Y):

$$Y = -0.8898x_{\text{motor time [SRT]}} - 0.6672x_{\text{median direction deviation [ZBA]}} + 104.5585$$

In order to estimate the impact of psychomotor abilities [SRT, CRT, and ZBA] on the “too small” range of goalkeepers’ movement in relation to the ball flight path, we used regression analysis. The model turned out to be significant ($F_{(2,7)} = 17.576$, $p = 0.00187$, $SE = 4.81\%$) and the predictors obtained through it explained 83.39% of the dependent variable ($R^2 = 0.8339$). The level of motor time [SRT] ($\beta = -0.8898$, $p = 0.000751$) and the median deviation in direction had a significant impact on the “too small” range of goalkeepers’ movement in relation to the ball’s path [ZBA] ($\beta = -0.6672$, $p = 0.003562$).

Discussion

The results presented herein indicate that the level of selected psychomotor abilities differentiates the actions of goalkeepers, and that there are strong significant correlations between the variables analyzed in this study.

The findings show differences in the percentage of fast-paced saves after a delay, depending on the level of simple reaction time [SRT]. It can be assumed that the difference is due to the fact that players with a longer reaction time need more time for cognitive processing, and thus make “fast-paced saves after a delay”. The same arguments can explain the differences in taking actions (fast-paced saves after a delay) depending on the level of reaction time with choice [CRT], which are on the borderline of the adopted threshold for statistical significance.

The differences between goalkeepers in the accuracy of their movement relative to the ball’s trajectory (wrong direction, correct height) depending on the level of reaction time with choice [CRT] may indicate that a longer cognitive processing time allows a better determination of the throw height. This may result from a longer time deciding on the direction of movement, which gives the opportunity to observe the thrower for a longer time and make a decision based that movement and on the position of the throwing arm. This is also supported in research by Loffing and Hageman (2014).

The results on the level of psychomotor abilities correspond to the data obtained by other authors (Przednówek et al., 2019; Krawczyk et al., 2018). The data from the current study also indicate the relationship between the level of psychomotor abilities and the level within professional sport. This is also confirmed by the research of other authors who deal with the exploration of the analyzed problem, (Simonet et al., 2019; Biscaia et al., 2018; Yüksel&Tunç 2018; Maghsoudipour et al., 2018; Helm et al., 2016). Biscaia et al. (2018) demonstrated that targeted training reduces reaction time, which further confirms the results of the current study.

When discussing the results in the area of goalkeepers’ actions depending on the psychomotor ability to anticipate time, we should point to the difference in the percentage of saves without reducing the defensive area within the stance between the studied goalkeepers. It can be stated that the players examined in this study who had a lower level of psychomotor ability to anticipate make saves without reducing the defensive area within their stance to extend the time necessary to decide on the type of save, and thus to initiate a reaction. The results also demonstrate differences at the “earlier” initiation of the save, as well as differences (at the threshold of the adopted level of statistical significance, $p=0.06$) at the “late” initiation of the save depending on the level of time anticipation [ZBA]. The problem so diagnosed can be explained by the fact that players with a lower level of time anticipation, in order to compensate for this deficit, make “earlier” saves. It can also be assumed that players with a higher level of anticipation have a predisposition to delay a save, which means that they wait longer to perform a defensive action. When a player is throwing a ball at high speed, the goalkeepers have too little time to react, which may result in a higher percentage of late saves.

The analysis of these results indicated differences in the type of saves depending on the psychomotor level of the ability of place anticipation. Goalkeepers with a higher level of this ability perform fewer saves “after reducing the defensive area within the stance,” and more saves “after reducing the defensive area with a step out/dive” This may be due to the fact that players with a higher level of anticipation of the place better predict the throw at the moment of the throw based on the movements and positioning of the thrower, thus making the right movement at the right time towards the ball flying at the goal (thrown outside the goalkeeper’s range of motion). Loffing and Hageman present similar observations in their research (2014).

The results regarding the level of psychomotor abilities correspond to the data presented by other authors (Przednówek et al., 2019; Krawczyk et al., 2018). The literature on the subject shows that the level of anticipation (time and place) largely depends on professional experience (Biscaia et al., 2018; Rojas et al., 2012) and professional level (Simonet et al., 2019; Maghsoudipour et al., 2018), which corresponds to the results presented in this study, covering players with the highest athleticism in the highest competition class in Poland. The results regarding psychomotor anticipation ability are confirmed by Loffing and Hageman (2014), who demonstrate differences in making decisions about the save, suggesting that goalkeepers at a higher professional level are able to register and use a greater number of stimuli than goalkeepers at a lower level.

When discussing the relationship between the level of selected psychomotor abilities and the actions of goalkeepers in the type of save, it should be noted that the strongest and most statistically significant correlations were recorded between “place anticipation” and the percentage of saves “after reducing the defensive area within the stance” ($r_s=0.91$, $p<0.05$), and “after reducing with a step out/dive” ($r_s=-0.90$, $p<0.05$). The results suggest that players with a higher level of “anticipation of place” “after reducing the defensive area” more often move towards the flying ball. Players with a lower level of place anticipation are more likely to intervene “after reducing the defensive area within the stance.” This is confirmed in the studies by Loffing and Hageman (2014), who conclude that goalkeepers predict the place of the throw on the basis of specific movement and body position of the throwing players.

The results also show significant correlations at the time of the save. High interrelation values at the $r_s=0.77$ ($p<0.05$) [SRT] and $r_s=0.66$ ($p<0.05$) [CRT] level were obtained between the “fast-paced save after a delay” and the simple reaction time and reaction time with choice, which may suggest that players with a longer reaction time need more time to process the information, which means that they wait longer to start the move, which generates a higher percentage of fast-paced saves after a delay. The findings also show a strong

correlation between the psychomotor ability to anticipate time [ZBA] and the “earlier” initiation of the save ($r_s=0.70$, $p<0.05$). This statistical finding should be interpreted to mean that there is a strong relationship between the psychomotor anticipation of time and the time of the save. In game conditions, goalkeepers with a lower level of this ability have a weaker reading of the moment the ball is thrown by the attacker and in order to increase the likelihood of defense, they start intervening earlier (before the ball leaves the thrower’s hand), unlike players with a higher level of this ability.

The high correlation between the level of reaction time with choice [CRT] $r_s=0.67$ ($p<0.05$) and the “wrong direction and correct height” of the save clearly suggests that shorter reaction time with choice is manifested by eliminating the save in the “wrong direction and correct height.”

A high correlation between motor time [SRT] and the “optimal” range of the goalkeeper’s movement relative to the ball’s flight path was observed ($r_s=0.78$, $p<0.05$). The correlation coefficient illustrated in this way suggests that goalkeepers obtaining longer motor time in tests report a greater number of saves with an optimal range of movement relative to the ball’s trajectory.

In the case of the relationship between the motor time level [SRT, CRT] and the “correct” save technique, we obtained $r_s=0.68$ ($p<0.05$) and $r_s=0.67$ ($p<0.05$), respectively, which suggests that goalkeepers obtaining longer motor time in the SRT and CRT tests perform more saves with the “correct” technique-under the conditions of the study. In addition, this is confirmed by the analysis of the relationship between the level of motor time and the “inadequate” save technique in which inverse correlation coefficients were obtained ($r_s=-0.68$, $p<0.05$ [SRT]; $r_s=-0.67$ ($p<0.05$) [CRT]).

It is interesting to look at the registered correlation coefficient $r_s=0.73$ ($p<0.05$) between the motor time level in the SRT test and the percentage of “successful” saves (defended), which suggests that goalkeepers with a longer reaction time report a greater number of effective interventions. Moreover, this is confirmed by the analysis of the relationship between the level of motor time and the “unsuccessful” save effect, in which the inverse correlation coefficients $r_s=-0.73$ ($p<0.05$) were obtained. It should also be pointed out that throws with a lower ball velocity are more effective (Vila et. al., 2020).

The results of regression analysis also indicate strong relationships between the level of selected psychomotor abilities and the actions of goalkeepers when defending throws in a fast break, which was reflected in three models. The first model shows that the percentage of “earlier” saves depends on the level of time anticipation, which shows that goalkeepers achieving a longer anticipation time perform “earlier” saves more often. The second regression model that we built shows that the “optimal” range of the goalkeeper’s movement relative to the ball’s path depends on the motor time [SRT]. Goalkeepers with longer motor time have a higher percentage of saves, interpreted as “optimal” range of movement in relation to the ball’s path.

The third regression model indicates the relationship between motor time [SRT] and anticipation of the direction [ZBA] and the “too small” range of movement. The results suggest that longer motor time [SRT] and weaker anticipation of where the object will appear in the ZBA test reduce the number of saves with a “too small” range of motion in the group of the studied goalkeepers during saves in a fast break.

Our study and the results we gathered indicate that the goalkeeper’s save is a series of motor-mental operations, and the effect of the save is only the last sequence of a series of actions in the entire save process, as noted by Norkowski (1996, 1997). Furthermore, the analysis according to the adopted concept allows us to pinpoint the characteristic actions of the goalkeeper in a fast break situation, as well as the presumed reasons for ineffective saves, and shows opportunities for optimizing the training process. Hatzimanouil (2019) also indicates that recording of only the percentage level of effectiveness of goalkeeper’s saves is insufficient and that other factors should be sought for a comprehensive analysis and evaluation of the game in terms of the position of goalkeeper.

Limitations

The research was conducted at the second-highest level of play (Polish PGNiG Superleague). The psychomotor tests were carried out only on the dominant upper limb. In order to verify and generalize the conclusions and the possibility of presenting the practical application for training and matches, further research should be conducted on a larger group of players with different professional levels, at different tournament levels, also taking into account tests on the non-dominant upper limb and on the lower limbs.

Conclusions

An analysis of the findings indicate that the level of psychomotor abilities is an important factor which differentiates goalkeepers’ actions in a fast break situation. The highest differentiation was revealed in the case of the psychomotor ability to anticipate time [ZBA], followed by the reaction time with choice [CRT]; the lowest was in the case of simple reaction time [SRT]. The strongest correlations were found between psychomotor anticipation of the place and the number of saves after reducing the defensive area within the stance and “after reducing the defensive area with a step out/dive.” There was a slightly lower correlation for motor time [SRT] and “optimal” range of motion; simple reaction time [SRT] and the number of fast-paced saves after a delay; motor time [SRT] and the “successful” and “unsuccessful” result of the save; and anticipation of time [ZBA] and the “earlier” initiation of the save. All of these correlations were statistically significant and shared the same direction of dependence, which indicates that a lower level of psychomotor abilities in terms of reaction time,

motor time, and space-time anticipation determines a higher quality of goalkeepers' actions in the event of fast attack throws. We have shown that the level of anticipation of time [ZBA], motor time [SRT], and anticipation of place [ZBA] are predictors of specific actions of goalkeepers in the situation of throws in a fast attack. The recognized problem of the relationship between the level of psychomotor preparation and goalkeeping is very interesting, and proves that training programs focused on shaping the high level of analyzed psychomotor abilities do not guarantee high quality and effectiveness of goalkeeper saves in the event of fast break throws.

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Disclosure of interest

The authors report no conflict of interest.

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