

Relationship between speed, strength, lower limb power and agility in special forces soldiers

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Published online: December 31, 2025

Accepted for publication: December 15, 2025

DOI:10.7752/jpes.2025.12269

Abstract:

Introduction: Soldiers in special forces units must demonstrate a high level of motor skills, with agility being a critical component being a critical component. Agility is believed to be essential for the effective performance of combat tasks and may so serve as an indicator of injury risk. Despite its importance, the agility in soldiers often receives insufficient attention. **Purpose:** This study aimed to evaluate both planned and reactive agility in special forces soldiers and to identify the motor abilities that influence agility levels. **Material:** The research included 74 special forces soldiers, with an average age of 25.65 ± 6.10 years. **Method:** Planned agility was assessed using the Pro-agility test, while reactive agility was evaluated with the Random 50 run test on the Skillcourt device. Lower limb power was assessed using three jump tests: Squat Jump, Countermovement Jump, and Countermovement Jump with Arm Swing. Speed was evaluated with a 30-meter sprint. Maximal isometric strength was assessed using the Isometric Mid-Thigh Pull (IMTP) test. **Results:** The analysis revealed statistically significant relationships between planned agility and both lower limb power and speed. No statistically significant relationships were observed between reactive agility and other motor abilities. **Conclusions:** The key motor abilities that may determine the level of planned agility are speed abilities and lower limb power. The lack of a relationship between reactive agility and the tested motor abilities may be due to the fact that reactive agility is primarily determined by cognitive abilities.

Key Words: military, army, special operations forces, reactive agility, motor skills

Introduction

Agility is considered a significant component of physical fitness, which may be related to health status and can play a key role in certain professional activities (e.g., in the military) (Krolo et al. 2020). It is worth noting that agility can be divided into two elements: CODs (change of direction speed) and RAG (reactive agility). CODs is defined as pre-planned agility (non-reactive, closed skill), which refers to the ability to quickly change direction without reacting to an external stimulus (Krolo et al. 2020; Popowczak et al. 2021; W. B. Young et al. 2015; Matlák et al. 2016; Sekulic, et al. 2014). There are certain factors that determine the level of this ability, such as technical skills (Born et al. 2016), sprint speed, and jump height (Krolo et al. 2020; Turner 2011). RAG, also known as unplanned agility (reactive, open skill) (Krolo et al. 2020; Matlák et al. 2016), requires perceptual and cognitive abilities (visual processing, spatial recognition, reaction speed, ability to distinguish between the left and right side and the ability to make quick decisions and anticipation), which are crucial for reactive agility (Krolo et al. 2020; Turner 2011; Popowczak et al. 2021; Siyah et al. 2023). RAG is an important aspect to study because, in most situations, a change in direction is triggered by an unexpected external stimulus, such as unpredictable opponent actions (Turner 2011; Sekulic, Uljevic et al. 2017). The ability to respond to unpredictable stimuli is one of the key elements of Special Operations Forces operators' functioning, enabling them to operate effectively in dynamic and demanding operational environments (LaCroix et al. 2024). It should be emphasized that CODs and RAG are two different abilities that should be considered separately (W. B. Young et al. 2015).

In order to better understand agility, the authors seek to identify the relationship between agility and selected motor abilities (Papla et al. 2020; Sassi et al. 2009; Nimphius et al. 2018). Papla et al. (2022) seek to find a relationship between lower limb strength and power and linear speed, which determines the level of planned agility. Sassi et al. (2009) in their work applied a modified T-test (MAT), characterized by shorter running segments between cones. This modification aimed to assess the relationship between strength and planned agility. Nimphius et al. (2018) also believe that shorter distances during CODs trials reduce the

influence of linear speed on the final result. In this way, we can reliably assess the ability to change running direction (Nimphius et al. 2018).

Individuals belonging to uniformed services must maintain their physical fitness at a high level throughout their service period (Canham-Chervak et al. 2010; Rosendal et al. 2003), where strength, speed, agility (Sporiš et al. 2012; Dijkma, Perry et al. 2019), aerobic, and anaerobic endurance are fundamental (Kraemer et al. 2004; Dijkma, Perry et al. 2019; Maupin et al. 2018). The authors suggest that the level of motor skills in soldiers should be at the level of elite athletes (Bovill et al. 2003; Sporiš et al. 2012). According to Maupin et al. (2018), Pryor et al. (2012), and Simpson et al. (2017), the main motor skills of soldiers include aerobic endurance and muscle strength. It is believed that these motor skills are related to combat effectiveness and may be one of the predictors of injury risk (Maupin et al. 2018; Pryor et al. 2012; Simpson et al. 2017). Soldiers perform their service in various environmental conditions, where during marches, they are forced to carry heavy equipment, depending on the requirements of the given combat task. The carried equipment includes protective elements (e.g., helmet and bulletproof vest), combat elements (ammunition, weapons), and food rations (Fallowfield et al. 2012). The additional load can even exceed 40 kg (Halvarsson et al. 2018; Glad et al. 2012; Goff et al. 2011). Special forces units must carry these loads for long periods, covering distances often exceeding 20 km (Orr et al. 2021; Fallowfield et al. 2012). During the march, there may also be sections where the body is forced to perform intense and short efforts in the form of sudden sprints (Sporiš et al. 2012; Dijkma, Perry et al. 2019; Harman et al. 2008). These extreme physical efforts faced by military units lead to numerous injuries and overloads of the musculoskeletal system (Robinson et al. 2016; Rosendal et al. 2003). Such body loads contribute to reduced combat effectiveness (Roy et al. 2012; Dijkma, Arslan et al. 2020).

Based on current scientific knowledge, Bullock et al. (2010) developed six injury prevention strategies for the military community. One of them is the recommendations of the Joint Physical Training Injury Prevention Working Group (JPTIPWG), which suggests that the correct approach to preventing lower limb injuries is to introduce exercises into training that change the load on the musculoskeletal system in multiple planes. An example of such an intervention is agility training (Canham-Chervak et al. 2010; Bullock et al. 2010; Dijkma, Perry et al. 2019; Wardle and Greeves 2017; Jones et al. 2018), which not only prevents injuries but also improves fitness parameters. Studies by Harman et al. (2008) show that individuals who included agility and cardiovascular exercises in their training achieved better results in combat trials, such as weightlifting, obstacle course running, and rescuing others. Additionally, the authors claim that an additional benefit of agility exercises is the improvement of cognitive functions such as memory and spatial orientation (Lennemann et al. 2013; Lopes Filho et al. 2019; Andres et al. 2023; Dunskey 2019; Rogge et al. 2017). Moreover, agility exercises induce synaptogenesis in the motor cortex and cerebellum, which may influence cognitive functions essential during combat tasks (Lennemann et al. 2013). Andres et al. (2023) recommend incorporating agility training into military training, particularly focusing on motor coordination, which is associated with attention shifting, concentration, and logical thinking. Nindl et al. (2018) and Alim et al. (2023) argue that agility is regarded as an element of both physical and cognitive readiness in modern armed forces.

In summary, the literature review demonstrated the significant role of agility abilities, which can be crucial for soldiers of special forces units. They may be related to the effective execution of combat tasks and can be a key predictor of injuries. On the other hand, Jamro et al. (2022) point out that too little attention is paid to the level of soldiers' agility. Moreover, most studies focus solely on CODs without responding to an external stimulus, which is particularly important for soldiers of special forces units (Sporiš et al. 2012, Ross et al. 2023; Feeney et al. 2023). Horička et al. (2014) emphasize that agility is not only about simple reaction speed, acceleration, deceleration, or change of running direction, but also involves perceptual abilities, such as complex responses to unexpected and variable stimuli, which also occur during combat tasks. Previous studies show that candidates who successfully complete the selection process may exhibit a higher level of psychomotor abilities, which can be a component of reactive agility (Paško et al. 2022). The limited number of studies on reactive agility highlights a gap in assessing the relationship between lower limb speed, power, and strength and reactive agility. Therefore, the research also focuses on evaluating reactive agility using the modern Skillcourt technology. Therefore, the aim of our research was to assess the relationship between speed, strength, and power of the lower limbs and planned and reactive agility in soldiers of special forces units. The obtained results will help determine the agility, strength, speed, and power abilities that a special forces soldier should possess to meet the demands they face during combat tasks. Moreover, the obtained results will allow for understanding the impact of motor abilities such as strength, speed, and power on both planned and reactive agility in soldiers of special forces units.

Material & methods

Participants

The study involved 74 qualified men aged 25.65 ± 6.10 years belonging to an elite Military Unit. The soldiers had a body mass of 85.17 ± 8.25 kg and a body height of 180.38 ± 6.02 cm (Table 1). Each participant signed an informed and voluntary consent to participate in the study. The primary inclusion criterion was the absence of any health problems. Each participant was fully rested. Respondents could withdraw from the study

at any time. None of the participants were undergoing pharmacological treatment or sustained any injuries during the study. The scope and design of the study were approved by the Ethics Committee of the University of Rzeszów/Poland (resolution of 3/01/2021). All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethics Committee of the University of Rzeszów and with the 1964 Helsinki Declaration and its later amendments.

Table 1. Characteristics of the study group

Variable	x	Me	min	max	sd	V (%)
Age	35.65	34.00	26.00	51.00	6.098	17.11
Weight (kg)	85.17	84.75	68.50	104.70	8.246	9.68
Height (cm)	180.38	180.20	170.00	194.70	6.024	3.34
BMI (kg /m2)	26.13	25.80	22.60	29.90	1.672	6.40
FAT (kg)	14.74	14.30	7.90	24.50	3.583	24.30
FAT (%)	17.22	17.15	10.40	24.70	3.292	19.12
FFM (kg)	70.42	70.35	59.30	87.40	6.536	9.28
TBW (kg)	49.76	49.65	40.40	64.10	5.275	10.60

x – mean; Me – median; min – minimum; max – maximum; sd – standard deviation; V – coefficient of variation; BMI – body mass index; FAT – body fat; FFM – lean body fat; TBW – total body water

Measure

The study was conducted at the University Athletic Center for Innovative Sports Research in Rzeszów. Before starting the battery of tests, the respondents performed an extensive, individual warm-up lasting 15 minutes. The soldiers were thoroughly instructed on the correct way to perform each exercise. The participants approached each trial fully rested.

Power

The subjects were engaged in physical tasks that assessed the strength and power of the lower limbs using three different protocols for vertical jumps with the Optogait device. The first jump was the Countermovement Jump (CMJ). Respondents had to adopt an akimbo position, then on the signal of the instructor, bend their lower limbs at the knee joints to 90° and immediately perform the highest possible vertical jump (Markström i Olsson 2013). The next test was the CMJ with arm swing (CMJ AS). The jump procedure differed only in that the jump was performed with the use of an arm swing. The third test was the Squat Jump (SJ), which also started from a straddle position with hands placed on the hips. The SJ differed from the previous two in that respondents had to maintain the position with bent lower limbs at 90° for a period of 3 seconds, then perform a vertical jump (Samozino et al. 2008). During the flight phase, the lower limbs should be straightened to avoid bending, which could disrupt the reliability of the results (Markovic et al. 2004). The Optogait device measured the height of each jump, based on which the power of the lower limbs was calculated using the Sayers formula.

Reactive Agility Test

To assess reactive agility, the Random 50 run test was used, conducted on the Skillcourt device (Hülsdünker et al. 2023). Skillcourt features a 5x5 m board with 9 fields. All tasks appear on a screen located at the front of the square. Before the test, respondents positioned themselves on the central field in a straddle position. Upon confirming readiness, fields randomly appeared on the screen, to which the respondents had to run as quickly as possible. The final assessment was based on the time taken to cover a distance of 50 m (Friebe et al. 2023). The test was performed twice, with a 3-minute rest interval. If the respondents stumbled, the trial was canceled.

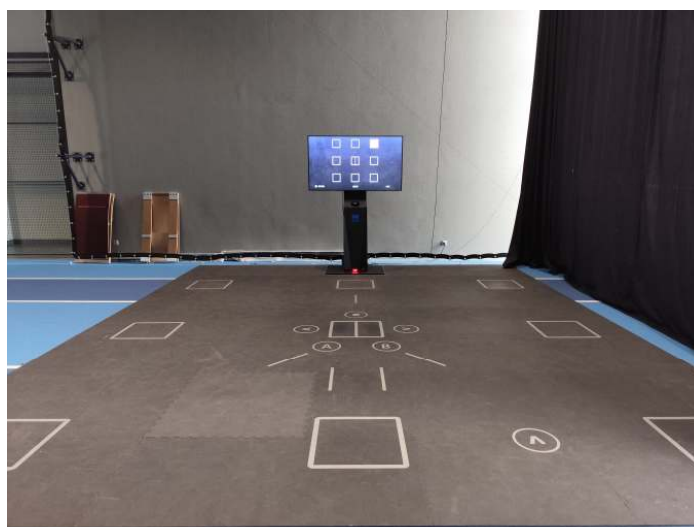


Figure 1. Skillcourt device and Random 50 run test

Change of Direction Speed

Planned agility (CODs) was assessed using the Pro-agility test. Time was measured and stopped by the Microgate electronic timing system with an accuracy of 0.01 s. Respondents started from the center line in a straddle position, with their left hand placed on the ground. On their own signal, they sprinted 5 meters to the left, where they had to touch the line with their left hand and foot, then immediately turned and ran to the right line, which they had to touch with their right hand and foot.

The test ended when they crossed the center line again. In total, respondents had to sprint 5 meters to the left, 10 meters to the right, and 5 meters back to the left. The shorter time from the two trials was used for analysis. If the soldiers did not touch the line with their hands or stumbled, the trial was repeated. The rest time between trials was 3 minutes to eliminate fatigue (Forster et al. 2021).

Speed

Additionally, to assess speed, a 30-meter sprint was conducted. Additionally, the time over 10 meters and 20 meters was analyzed. The trial was measured using the Microgate electronic timing device with an accuracy of 0.01 s. The athletes positioned themselves 30 cm from the starting line in a high stance. On their own signal, the respondents started and covered the 30-meter distance at maximum speed. The trial was performed once. The trial was repeated only if the soldier stumbled or, for some other reason, did not generate maximum speed.

Strength

The final element was the assessment of maximum isometric strength using the IMTP (Isometric Mid-Thigh Pull) test. Gamma dynamometric platforms were used for this study. The subjects had to stand on two force plates with their feet shoulder-width apart. The barbell height was individually adjusted to be at mid-thigh level for each respondent.

Participants gripped the bar with an overhand grip. On the instructor's signal, they performed an upward pull with maximum force under isometric conditions for about 5 seconds. The task was performed twice, with a 3-minute rest between sets. Each set was conducted with verbal encouragement (L. P. James et al. 2017). The final assessment considered the maximum force expressed in Newtons and the symmetry index (SI) between the right and left lower limbs, calculated using the formula (Sato i Heise 2012):

$$SI = \frac{(\text{higher value} - \text{lower value})}{\text{total value}} \times 100\%$$

Statistical analysis.

The study utilized basic statistical measures such as mean, median, minimum, maximum, standard deviation, and coefficient of variation to characterize the study group and assess selected motor abilities. Additionally, a dependency analysis was conducted using Spearman's rank-order correlation, as the variables deviated from a normal distribution. The normality of the variable distribution was analyzed using the Shapiro-Wilk test. Furthermore, multiple linear regression models were applied for planned and reactive agility. The analysis used values of unstandardized beta (β), standard error (SE), Residual Standard Error (RSE), the ratio of the mean regression sum of squares divided by the mean error sum of squares (F), multiple R-squared (R^2), and statistical probability (p). Statistical analysis was performed using Statistica 13, while multiple linear regression models were executed in Rstudio.

Results

The numerical characteristics of the fitness tests conducted are presented in Table 2. The highest jump height was achieved during the CMJ AS, which was 42.23 cm. Similarly, during the CMJ AS, the soldiers achieved the highest relative and absolute power values, which were 4376 W and 51.29 W/kg, respectively. The smallest variation in results for jump height, relative power, and absolute power was observed for the SJ jump, while the CMJ jump showed the greatest variation in results for each variable.

The average speed achieved by the soldiers over 10, 20, and 30 meters was 1.94 s, 3.27 s, and 4.55 s, respectively. It is worth noting that the smallest variation in times was observed over the 20-meter distance (4.1%). Agility analysis showed that during planned agility (Pro-agility test), the most consistent results were observed (3.6%), with an average time of 5.19 s. In terms of strength, the average maximum force was 2007.66 N, and the symmetry index was 6.52%.

Table 2. Numerical characteristics of power, strength, speed and agility

	x	sd	Me	min	max	V (%)
Power						
SJ height (cm)	34.27	5.35	33.95	23.20	47.10	15.606
SJ power (W)	3893.79	513.83	3911.31	2807.54	5036.27	13.196

SJ power (W/kg)	45.57	3.91	45.40	37.13	54.86	8.575
CMJ height (cm)	36.46	7.23	36.10	3.30	50.90	19.826
CMJ power (W)	4026.80	648.58	4089.29	1465.80	5618.99	16.107
CMJ power (W/kg)	47.04	5.34	46.91	20.00	56.23	11.358
CMJ AS height (cm)	42.23	7.51	42.40	26.80	76.90	17.792
CMJ AS power (W)	4376.96	603.31	4412.31	3159.52	6372.73	13.784
CMJ AS power (W/kg)	51.29	5.49	51.02	39.89	76.78	10.696
Speed						
10m sprint (s)	1.94	0.08	1.95	1.72	2.17	4.390
20m sprint (s)	3.27	0.14	3.28	2.95	3.65	4.131
30m sprint (s)	4.55	0.23	4.55	4.06	5.55	5.030
Agility						
Pro-agility test (s)	5.19	0.19	5.17	4.80	5.83	3.601
Random 50 run (s)	23.64	1.83	23.55	20.22	28.97	7.744
Strength						
IMTP strength (N)	2007.66	289.13	1990.00	1370.00	3190.00	14.402
SI (%)	6.52	5.70	5.98	0.05	25.35	87.390

x – mean; Me – median; min – minimum; max – maximum; sd – standard deviation; V – coefficient of variation; SJ – Squat Jump; CMJ – Countermovement Jump; AS – arm swing; IMTP – Isometric Mid-Thigh Pull; SI – Symmetry Index

The analysis of the relationship between jumping abilities and speed, agility, and strength is presented in Table 3. It was shown that speed abilities significantly correlate with tests assessing power. Each correlation coefficient is negative, indicating that the shorter the sprint time over a given distance, the higher the jump height and generated power. The highest correlation coefficient can be observed between the jump height in CMJ AS and the 20-meter sprint time (-0.54).

Significant differences were also found between power and the Pro-agility test. Negative correlation coefficients were also observed, meaning that the shorter the time in the Pro-agility test, the higher the values of jump height, relative power, and absolute power in each power test. The highest correlation strength for the Pro-agility test was observed between relative power in the SJ test and the CMJ AS test. No significant correlations were found between the Random 50 run test and the power tests. Similarly, no significant relationships were observed between the IMTP test and the symmetry index with the power tests.

Table 3. Correlation matrix between lower limb power and strength, speed, and agility

	10m sprint (s)	20m sprint (s)	30m sprint (s)	Pro-agility test (s)	Random run (s)	50 IMTP strength (N)	SI (%)
SJ height (cm)	-0.37*	-0.50*	-0.49*	-0.45*	-0.11	-0.01	-0.02
SJ power (W)	-0.29*	-0.36*	-0.37*	-0.29*	-0.07	0.09	-0.16
SJ power (W/kg)	-0.36*	-0.49*	-0.49*	-0.46*	-0.13	0.00	-0.02
CMJ height (cm)	-0.28*	-0.42*	-0.41*	-0.34*	-0.09	0.03	-0.08
CMJ power (W)	-0.26*	-0.33*	-0.32*	-0.24*	-0.08	0.06	-0.18
CMJ power (W/kg)	-0.28*	-0.41*	-0.41*	-0.34*	-0.11	0.02	-0.06
CMJ AS height (cm)	-0.47*	-0.54*	-0.52*	-0.45*	-0.09	0.05	-0.12
CMJ AS power (W)	-0.40*	-0.43*	-0.42*	-0.34*	-0.08	0.10	-0.18
CMJ AS power (W/kg)	-0.47*	-0.53*	-0.50*	-0.46*	-0.09	0.02	-0.10

SJ – Squat Jump; CMJ – Countermovement Jump; AS – arm swing; IMTP – Isometric Mid-Thigh Pull; SI – Symmetry Index; * – statistical significance

The relationship between speed and strength with planned and reactive agility is presented in Table 4. Significant correlations were observed between the Pro-agility test and the 10, 20, and 30-meter sprints. Each correlation coefficient is positive, indicating that the longer the time in the Pro-agility test, the longer the times in

the straight-line sprint. The highest correlation strength was observed between the 30-meter sprint (0.42), while the lowest was between the 10-meter sprint (0.24). No significant correlations were found between speed abilities and the Random 50 run test. Similarly, no significant relationships were observed between strength and the symmetry index with the Pro-agility test and the Random 50 run test.

Table 4. Correlation matrix between speed, strength, and agility

	Pro-agility test (s)	Random 50 run (s)
10m sprint (s)	0.24*	-0.01
20m sprint (s)	0.37*	0.04
30m sprint (s)	0.42*	0.06
IMTP strength (N)	0.05	-0.03
SI (%)	-0.02	0.16

MTP – Isometric Mid-Thigh Pull; SI – Symmetry Index;

* – statistical significance

The next step of the analysis involved linear regression models, which are presented in Tables 5 and 6. Table 5 provides a detailed assessment of the impact of jump height, relative and absolute power, speed, and strength on planned agility. The highest model fit values (0.23) were observed for jump height and relative power. The linear regression model for the Pro-agility test showed statistical significance for each variable. The intercept was statistically significant for each regression model.

For jump height and absolute power, no statistically significant variables were found that could determine the result in the Pro-agility test. It was shown that relative power achieved in the SJ test is a statistically significant predictive variable in the Pro-agility test. The β value is -0.018, which means that each increase in relative power in the test by one unit shortens the time in the Pro-agility test by 0.018 seconds. The standard error for relative power in the SJ test is 0.009 seconds. A statistically significant predictive variable was also observed for the 30-meter sprint speed. The result suggests that each additional second in the 30-meter sprint increases the time in the Pro-agility test by 0.336 seconds. This coefficient has an error of 0.091 seconds.

Table 5. Multiple Linear Regression for Pro-agility test – power

Variable	Pro-agility test (s)		RSE	R ²	F	p
	β	SE				
Jump height						
Intercept	5.753***	0.129				
SJ	-0.013	0.007	0.168	0.23	6.872	0.0004
CMJ	0.001	0.004				
CMJ AS	-0.004	0.004				
Power (W)						
Intercept	5.699***	0.161				
SJ	-0.001	0.001	0.177	0.14	3.795	0.0140
CMJ	0.001	0.001				
CMJ AS	-0.001	0.001				
Power (W/kg)						
Intercept	6.217***	0.232				
SJ	-0.018*	0.009	0.167	0.23	6.984	0.0004
CMJ	0.001	0.005				
CMJ AS	-0.004	0.006				
Speed and Strength						
Intercept	3.522***	0.460				
30m sprint (s)	0.336***	0.091	0.174	0.17	4.620	0.0053
IMTP strength (N)	0.001	0.001				
SI (%)	-0.001	0.004				

β – unstandardized beta; SE – standard error; RSE – Residual Standard Error;

F – the ratio of the mean regression sum of squares divided by the mean error sum of squares;

m. R² – multiple R-squared; * – $p < 0.05$; ** – $p < 0.01$; *** – $p < 0.001$

Table 6 presents linear regression models for the Random 50 run test. No regression model showed statistically significant differences. In each model, the intercept was statistically significant. For predictive variables, statistical significance was observed only for the symmetry index.

The result suggests that a higher symmetry index by one unit may result in a longer time by 0.077 seconds in the Random 50 run test. The standard error value is 0.037 s, while the model fit is 0.06.

Table 6. Multiple Linear Regression for Random 50 run test (s) – power

Variable	Random 50 run test (s)		RSE	R ²	F	p
	β	SE				
Jump height						
Intercept	24.613***	1.425				
SJ	0.001	0.073	1.849	0.02	0.534	0.6607
CMJ	0.027	0.042				
CMJ AS	-0.047	0.048				
Power (W)						
Intercept	24.185***	1.689				
SJ	0.001	0.001	1.851	0.02	0.465	0.7073
CMJ	0.001	0.001				
CMJ AS	-0.001	0.001				
Power (W/kg)						
Intercept	25.893***	2.553				
SJ	-0.005	0.097	1.843	0.03	0.693	0.5597
CMJ	0.028	0.052				
CMJ AS	-0.065	0.065				
Speed and Strength						
Intercept	23.201***	4.786				
30m sprint (s)	0.102	0.942	1.812	0.06	1.525	0.2156
IMTP strength (N)	-0.001	0.001				
SI (%)	0.077*	0.037				

β – unstandardized beta; SE – standard error; RSE – Residual Standard Error;

F – the ratio of the mean regression sum of squares divided by the mean error sum of squares;

m. R² – multiple R-squared; * – p<0.05; ** – p<0.01; *** – p<0.001

Discussion

The main aim of the study was to assess the relationship between speed, strength, and lower limb power with planned and reactive agility among special forces soldiers. The research showed that speed might be one of the motor abilities that significantly determines the level of planned agility. A shorter sprint time over each analyzed segment (10, 20, and 30 meters) can lead to a higher level of planned agility, meaning a quicker change of running direction. The confirmation of the impact of speed on planned agility can be seen in the results of multiple linear regression, which indicated that speed is a significant predictor. These findings are consistent with the studies of other authors (T. J. Gabbett et al. 2008; Bayraktar 2017; Vescovi i McGuigan 2008; Nimphius, McGuigan et al. 2010). Bayraktar (Bayraktar 2017) reached similar conclusions, also using the Pro-agility test and the 30-meter sprint with additional time measurements at 10 and 20 meters. Gabbett et al. (T. J. Gabbett et al. 2008) also observed a significant relationship between the 505 test and its modified version with the sprint times at 5 m, 10 m, and 20 m. On the other hand, there are studies where authors emphasize the lack of a significant relationship between planned agility and sprinting over various distances, especially in team sports such as field hockey or soccer (Wisløff et al. 2004; W. B. Young, McDowell et al. 2001). Wisløff et al. (Wisløff et al. 2004) did not observe a relationship between the shuttle run test and the 30-meter sprint in Norwegian soccer players. Young et al. (W. B. Young, McDowell et al. 2001) believe that the more complex the agility task, the less the influence of speed.

Regarding lower limb power, significant relationships were also observed with the Pro-agility test. The results suggest that higher values of jump height, relative power, and absolute power may correspond to a higher level of planned agility. In the case of multiple linear regression analysis, it can be observed that relative power in the SJ test may also significantly influence the level of planned agility. The study by Papla et al. (Papla et al. 2022) showed a very high and negative correlation between the time obtained after completing the planned agility test and the CMJ jump height ($r = -0.69$), while in our study, this relationship was -0.34 . Interesting findings come from two studies by Asadi et al. (Asadi, Arazi, W. B. Young et al. 2016; Asadi, Arazi, Ramirez-Campillo et al. 2017), which emphasized that plyometric training was a significant factor in improving CODs. Rodriguez et al. also reached similar conclusions, stating that jumps improve the performance of change of direction speed (Castillo-Rodríguez et al. 2012). According to the authors, several factors determine the speed of planned agility, including reactive strength, concentric strength (acceleration), and eccentric strength (deceleration) (Chaabene et al. 2018; Chaabene 2017; J. M. Sheppard and W. B. Young 2006). There are also articles where authors have shown a correlation between CMJ jump height and various tests assessing CODs (Barnes et al. 2007; Pauole et al. 2000; Peterson et al. 2006). This statement is consistent with the presented results. However, Malak reached different conclusions, not observing a significant relationship between the CMJ jump and the CODs test (Matlák et al. 2016). Sassi et al. (2009) studied the relationship between the MAT test and jumping and straight-line sprinting. The results were quite surprising, as MAT was not correlated with the other two variables in men, while different results were observed in women. The authors note that this is related

to the heterogeneity of the subjects. In this publication, a correlation can be observed between each indicator of lower limb strength and power and the test assessing planned agility, respectively for jump height (-0.45), relative power (-0.34), and absolute power (-0.46). An additional important aspect is the observation by Sheppard et al. (2006), who claim that the long distance covered in agility tests may affect the weaker relationship with lower limb strength and power.

In this study, no correlation was found between reactive agility and lower limb strength and power, which is consistent with the findings of other authors (Bayraktar 2017; Matlák et al. 2016; Henry et al. 2016). Researchers agree that the level of reactive agility is influenced not only by motor abilities but also by perceptual-cognitive abilities (T. J. Gabbett et al. 2008; Matlák et al. 2016; Henry et al. 2016; W. B. Young and Willey 2010; Farrow et al. 2005; T. Gabbett i Benton 2009; J. Sheppard et al. 2006). An example of such findings can be seen in the results of both Malak (Matlák et al. 2016) and Henry (Henry et al. 2016). Both studied the relationship between CMJ jump height and the time to complete a reactive agility test, with Henry's study involving unilateral jumps (Henry et al. 2016). The authors (Matlák et al. 2016; Henry et al. 2016) found no significant relationship between the parameters studied, leading to the conclusion that strength is not a significant factor influencing reactive movement agility. Different conclusions were reached by Hülsdünker et al. (Hülsdünker et al. 2023), who found moderate to high correlations between the components studied. The Skillcourt device includes three postulates that Wilke et al. (Wilke et al. 2020) identified as priorities for studying perceptual-cognitive functions, namely: lower limb movement speed, visuomotor processing, and cognitive skills (Wilke et al. 2020; Hülsdünker et al. 2023; Friebe et al. 2023). The last analyzed parameter was maximum isometric strength. The presented studies indicate that the strength obtained after performing the IMTP test did not correlate with either planned agility or reactive agility. The only predictive variable that showed significance in the multiple linear regression models was the symmetry index for reactive agility. However, this result is insufficient to draw definitive conclusions about the impact of symmetry on reactive agility. Dos'Santos et al. (Dos' Santos et al. 2018) in their article aimed to investigate the impact of symmetry between limbs in isometric contraction on CODs. The authors did not observe significant correlations between the studied parameters (Dos' Santos et al. 2018).

An important statement is the fact that, when comparing CODs and RAG skills, the latter are crucial for individuals in special forces units due to the multitude of unexpected stimuli that occur during combat tasks (Canalia 2017). As outlined in the introduction (Sporiš et al. 2012; Bovill et al. 2003), military personnel should possess physical abilities at the level of professional athletes. Pavlinovic et al. (Pavlinovic et al. 2022) indicate that in highly trained athletes, CODs is determined by anthropometric indicators and conditioning abilities, while perceptual and cognitive abilities determine the level of RAG. Much of this can be explained by the fact that highly trained athletes have already achieved a high level of fitness, while cognitive abilities are often genetically inherited and are not shaped in the training process as much as the former (Pavlinovic et al. 2022).

The main limitation of the study is the lack of assessment of cognitive abilities, which would help better define predictors that can significantly improve the level of reactive agility. The study results show that motor abilities alone are not sufficient predictors of reactive agility level, suggesting that cognitive abilities may be important. Another limitation is the lack of a control group, which would better define the level of motor abilities in special forces soldiers. Additionally, it would help better understand how motor abilities change during training and military service.

Future studies should expand the battery of agility tests to obtain more detailed information. The Skillcourt device is new, with few publications, so comparing it with other, more common tests would help utilize the device more broadly, not just for assessing reactive agility. Furthermore, future research should include additional analysis of perceptual-cognitive functions to confirm current speculations based on other authors' reports. Additionally, it is worth expanding the battery of tests assessing muscle strength, as only isometric strength analysis was conducted.

The obtained results can serve as a benchmark for the motor level that special forces soldiers should achieve. The results can be useful for special forces soldiers recovering from injuries and returning to full fitness, as well as for candidates preparing for selection to meet the tasks they will face. Moreover, the results can support the planning process of motor preparation for candidates and special forces soldiers.

Conclusions

Based on the conducted research, several key conclusions can be drawn regarding the relationship between lower limb motor abilities and planned and reactive agility in special forces soldiers:

1. The results indicate that speed and lower limb power have a significant impact on planned agility (CODs). Shorter sprint times over the analyzed distances (10, 20, and 30 meters) are associated with a higher level of planned agility, meaning faster changes in running direction. These indicators were confirmed in multiple linear regression analysis, which showed that speed is a significant predictor of planned agility.

2. The analysis demonstrated a significant relationship between lower limb power and performance in the Pro-agility test, suggesting that greater jump height, relative power, and absolute power correlate with a higher level of planned agility.
3. No significant relationships were found between reactive agility (RAG) and lower limb strength, power, or speed. These results confirm that the level of reactive agility is largely determined by perceptual-cognitive abilities, such as visuomotor processing, anticipation, and rapid decision-making in response to external stimuli. In this context, measuring motor abilities alone is insufficient to fully understand the predictors of reactive agility, indicating the need for future research to include an assessment of perceptual-cognitive functions.
4. The results show that isometric strength of the lower limbs and the symmetry index are not significant predictors of either planned or reactive agility. This implies that training aimed at improving agility should focus more on dynamic motor abilities and cognitive functions rather than solely increasing isometric strength.

In summary, the main contribution of this study is demonstrating that improving lower limb speed and power can significantly influence planned agility, while the development of reactive agility requires consideration of perceptual-cognitive abilities. These findings have practical applications in the training and preparation of special forces soldiers and provide a foundation for further research on integrating motor and cognitive functions in agility training.

Conflicts of interest - The authors declare no conflicts of interest.

The authors declare that no generative AI or AI-assisted technologies were used in the writing, editing, or preparation of this manuscript.

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