

Frequency of Dribbling as a Form of Speed Manifestation in Highly Qualified Female Hockey Players

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Abstract: This study investigated the relationship between hand movement frequency during dribbling and sensorimotor reaction speed in elite female hockey players. Simple visual-motor reaction (SVMR) and central nervous system activation were assessed using the Psychophysiological UPFT-1/30 apparatus. Statistical analysis revealed significant associations: rotational hand movements under fatigue correlated inversely with SVMR speed ($r = -0.698$, $p < 0.01$) and positively with error rates ($r = 0.579$, $p < 0.05$). Additionally, older players exhibited a lower ratio of total delay to lead time in the "Reaction to a moving object" test ($r = -0.698$, $p < 0.01$). Principal Component Analysis identified three main components explaining 78.27% of the total variance: an integrated sensorimotor coordination dimension (PC1 = 45.96%), anthropometric-strength traits (PC2 = 17.45%), and reaction accuracy (PC3 = 14.86%). Overall, while constrained by a small sample size, these findings highlight the multidimensional nature of elite hockey performance, where neuromotor regulation accounts for the largest share of inter-individual variability.

Keywords: Field hockey, Stick rotation frequency, Simple visual-motor reaction, Reaction to a moving object, Highly skilled female hockey players.

Introduction

Research on field hockey stick-handling technique remains limited [11-14]. Key components of effective stick handling include movement speed [15], reaction speed, the frequency of wrist rotational movements in the leading hand (pronation-supination), intermuscular coordination [12], and the aesthetic quality of hockey technique, which is largely determined by wrist-driven stick rotations, influencing both skill and individual style.

The technique of stick handling is strongly shaped by athletes' physiological mechanisms and anthropometric characteristics. Factors such as the frequency of puck or ball transfers and the amplitude of movements significantly affect the effectiveness of dribbling against opponents [7]. Movement frequency is one manifestation of speed-related abilities [10] and is closely linked to reaction speed. Despite its importance, there is a notable lack of literature on technical methods for training and improving stick and ball (or puck) handling [12], and quantitative assessments of these skills are virtually absent.

Given that stick-handling technique relies on coordinated sequential movements not only of the hands but also of the entire upper shoulder girdle, it is essential to study the speed of various types of athlete reactions. The frequency of movements and reaction speed are influenced by the number of engaged muscle chains, intermuscular coordination, and the frequency of nerve impulses transmitted from sensory analyzers to the central nervous system and then to the executing organs [9].

The purpose of the study was to identify the relationships and interdependencies between two forms of speed manifestation in highly skilled hockey players: movement frequency and reaction speed. The results were analysed using correlation analysis, InterCriteria analysis (ICrA) and Principal Component Analysis (PCA). ICrA complemented the correlation analysis by evaluating the degree of consonance and dissonance among the investigated performance indicators, allowing the identification of mutually related and relatively independent functional characteristics. PCA is very suitable for the considered dataset, even though the sample size is relatively small (13 athletes). PCA is an exploratory multivariate analysis rather than an inferential statistical model.

Materials and methods

Experimental procedure and data collection

The study was conducted at the Innovation Center of the Russian Olympic Committee (ROC) in Kislovodsk during the training camp of the women's field Hockey Club (HC) Dinamo-Elektrostal (Elektrostal, Moscow Region, Russia) in the preparatory period of February-March 2024. The participants included 13 female hockey players, all of whom were champions of Russia in field hockey and indoor hockey between 2021 and 2023. The athletes' average age was 22.7 ± 4.13 years, and their average weight was 57.6 ± 6.9 kg. All participants held the title of Master of Sports of the Russian Federation. Ethical approval and permission to conduct the research were obtained prior to data collection.

Wrist movements were detected by a MPU9250 module sensors (TDK Corporation, Japan), which recorded stick rotation. This module sensor combines a 3-axis gyroscope, a 3-axis accelerometer and a 3-axis magnetometer which are integrated into a single package. The sensor was located on the underside of the stick, approximately 15-20 cm above the blade. Sensor position information was transmitted wirelessly at 1000 Hz to a personal computer.

During the recordings, the initial body position of the subjects was a static, asymmetrical crouched stance, designed for field hockey ball control. The pose is characterized by considerable anterior trunk flexion at approximately a 45-degree angle relative to the hips, which lowers the subject's center of mass for improved stability and visual focus on the ground. Both legs were positioned in a staggered-width stance to provide a stable base of support along the sagittal plane. The right knee and hip exhibit greater flexion than the left, effectively lowering the right side of the pelvis. Both feet were oriented primarily forward, with the majority of the weight seemingly distributed over the front foot. The subject's upper

limbs extended downward and forward to grip a stick. Both shoulders were in a position of slight flexion and adduction. The right elbow was noticeably more flexed than the left, and the right wrist was more flexed to control the angle of the stick's blade against the floor, while the left arm remains more extended. This creates a low-profile, balanced posture that facilitates precise manual control over the stick. The gaze was directed inferiorly toward the contact point between the stick's blade and the floor surface.

Stick rotation frequency

One month prior to the training camp, a 15-second dribbling-in-place test was conducted to study the rotation frequency of the stick with the left hand. Using specialized software [13] and patent [8], the frequency of stick movements of female hockey players was analyzed. Rotation frequency was recorded as the number of pronation-supination movements of the left hand over intervals of 0-5 s, 5.1-10 s, 10.1-15 s, and the total 15 s. MPU9250 module sensors (TDK Corporation, Japan) were used to detect stick rotations at a sampling rate of 1000 Hz. The paired parameters were analyzed using Pearson correlation coefficients.

Simple visual-motor reaction

The simple visual-motor reaction (SVMR) test was used to assess the level of central nervous system activation in response to visual stimuli. Athletes were presented with 35 light stimuli, the first five of which served as practice, and the remaining 30 as test trials. Participants were instructed to press the "YES" button as quickly as possible upon presentation of the light stimulus. The initial body position of the subjects was already described above. Reaction time (RT, ms) was measured as the average time across 30 qualifying trials. Individual RT was defined as the interval between the appearance of the stimulus and the participant's response. Variability (ms) was calculated as the standard deviation of RT errors were recorded as the sum of anticipations (responses with RT < 100 ms) and omissions (responses with RT > 500 ms).

Anticipatory reaction (AR) to a moving object

To evaluate individual characteristics of the nervous system regarding speed and accuracy of responses to spatiotemporal events, as well as the balance of excitation and inhibition processes, the reaction to a moving object test was used. Both tests were conducted using the portable psychophysiological UPFT-1/30 testing device (Medicom MTD, Russia). Measured indicators included:

- Accuracy: proportion of responses whose latent period differed by no more than 50 ms from the ideal RT;
- Variability: standard deviation of the absolute difference between actual and ideal RT;
- Nervous system (NS) balance: ratio of total delay time to total lead time in absolute value [5].

InterCriteria analysis

Following the framework introduced in [2], the level of the degrees of "agreement" and "disagreement" between a pair of criteria evaluating various items is represented using an Intuitionistic Fuzzy Pair (IFP) [3]. An IFP consists of two non-negative real numbers representing the measures of "agreement" and "disagreement".

The process begins with an Index Matrix (IM) [1] where the row headers correspond to the criteria and the column headers correspond to the evaluated items, with matrix entries consisting of real values.

Let us have an IM:

$$AA \equiv \begin{array}{c|ccccccc} & O_1 & \cdots & O_k & \cdots & O_l & \cdots & O_n \\ \hline C_1 & a_{C_1, O_1} & \cdots & a_{C_1, O_k} & \cdots & a_{C_1, O_l} & \cdots & a_{C_1, O_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_i & a_{C_i, O_1} & \cdots & a_{C_i, O_k} & \cdots & a_{C_i, O_l} & \cdots & a_{C_i, O_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_j & a_{C_j, O_1} & \cdots & a_{C_j, O_k} & \cdots & a_{C_j, O_l} & \cdots & a_{C_j, O_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ C_m & a_{C_m, O_1} & \cdots & a_{C_m, O_k} & \cdots & a_{C_m, O_l} & \cdots & a_{C_m, O_n} \end{array}$$

where for every p, q ($1 \leq p \leq m, 1 \leq q \leq n$):

- C_p is a criterion, taking part in the evaluation;
- O_q is an object being evaluated;
- a_{C_p, O_q} is a real number or another object, that is comparable about relation R with

other a – object, so that for each $i, j, k : R(a_{C_k, O_i}, a_{C_k, O_j})$ is defined. Let $\bar{R}$ be the inverse relation of R . For example, if “ R ” is the relation “ $<$ ”, then $\bar{R}$ is the relation “ $>$ ”, and vice versa.

Let $S_{l,k}^\mu$ be the number of cases in which $R(a_{C_k, O_i}, a_{C_k, O_j})$ and $R(a_{C_l, O_i}, a_{C_l, O_j})$ are simultaneously satisfied. Let $S_{k,l}^\nu$ be the number of cases in which $R(a_{C_k, O_i}, a_{C_k, O_j})$ and $\bar{R}(a_{C_l, O_i}, a_{C_l, O_j})$ are simultaneously satisfied. Obviously,

$$S_{l,k}^\mu + S_{l,k}^\nu \leq \frac{n(n-1)}{2}.$$

Now, for every k, l such that $1 \leq k < l \leq m$, and for $n \geq 2$, it can be defined:

$$\mu_{C_k, C_l} = \frac{2S_{k,l}^\mu}{n(n-1)}, \quad \nu_{C_k, C_l} = \frac{2S_{k,l}^\nu}{n(n-1)}.$$

Therefore, $\langle \mu_{C_k, C_l}, \nu_{C_k, C_l} \rangle$ is an IFP. The following IM can be constructed:

$$\begin{array}{c|cccc} & C_1 & \cdots & C_m \\ \hline C_1 & \langle \mu_{C_1, C_1}, \nu_{C_1, C_1} \rangle & \cdots & \langle \mu_{C_1, C_m}, \nu_{C_1, C_m} \rangle \\ \vdots & \vdots & \vdots & \vdots \\ C_m & \langle \mu_{C_m, C_1}, \nu_{C_m, C_1} \rangle & \cdots & \langle \mu_{C_m, C_m}, \nu_{C_m, C_m} \rangle \end{array}$$

It determines the degrees of correspondence between criteria $C_1, \dots, C_m$. Here μ_{C_k, C_l} and ν_{C_k, C_l} are the “degree of agreement” and “degree of disagreement”, respectively.

Results

The obtained results of the female field hockey players from the HC Dinamo-Elektrostal team in the preparatory period are summarized in Tables 1 – 3. Table 1 presents the SVMR and AR observed values. Table 2 shows observed hand strength indicators.

Table 1. Simple visual-motor reaction and anticipatory reaction of female hockey players from the HC Dinamo-Elektrostal team during the preparatory period

No	Player	Age, years	Weight, kg	Anticipatory reaction			Simple visual-motor reaction		
				t, s	Variability, ms	NS	t, s	Variability, ms	Errors, qty
1	P1	19	45	67	40	2.49	213	42	0
2	P2	25	60	40	81	1.36	201	21	1
3	P3	16	63	47	34	7.60	271	46	1
4	P4	18	65	83	42	2.89	200	25	1
5	P5	21	63	47	65	1.77	188	20	6
6	P6	24	53	57	66	2.68	234	83	2
7	P7	19	52	43	60	3.62	240	33	0
8	P8	31	63	50	106	0.78	196	40	2
9	P9	24	63	50	57	0.90	197	33	4
10	P10	23	48	40	65	1.49	233	52	0
11	P11	24	57	63	66	1.89	193	30	0
12	P12	28	65	33	84	1.78	228	38	0
13	P13	23	52	50	74	2.97	208	30	0
$M \pm \delta$		22.70 ± 4.10	57.60 ± 6.90	51.50 ± 13.30	64.60 ± 19.50	2.40 ± 1.80	215.50 ± 24.10	37.90 ± 16.50	1.30 ± 1.80

Table 2. Hand strength indicators of female hockey players from the HC Dinamo-Elektrostal team during the preparatory period

No	Player	Power indicators			
		Left hand, mm	Right hand, mm	Power, %	Dissymmetry
1	P1	272	257	60	5
2	P2	342	318	56	7
3	P3	284	293	47	-3
4	P4	384	346	57	10
5	P5	319	303	50	5
6	P6	360	338	67	6
7	P7	305	301	50	1
8	P8	351	321	55	9
9	P9	289	271	45	6
10	P10	270	261	56	3
11	P11	328	278	54	15
12	P12	458	441	70	4
13	P13	273	280	54	-3
$M \pm \delta$		325.70 ± 54.20	308.30 ± 48.70	55.40 ± 7.10	5.00 ± 5.00

Table 3 reports the left hand stick rotation frequency during the 15-second dribbling-in-place test.

Table 3. Left hand rotation frequency during the 15-second dribbling-in-place test of female hockey players from the HC Dinamo-Elektrostal team during the preparatory period

No	Player	Number of rotations during dribbling			Sum in 15 s, qty
		0-5 s	5.1-10 s	10.1-15 s	
1	P1	12	11	11	34
2	P2	13	12	11	36
3	P3	12	10	10	32
4	P4	13	12	12	37
5	P5	12	11	13	36
6	P6	13	14	13	40
7	P7	12	11	11	34
8	P8	14	13	13	40
9	P9	12	10	13	35
10	P10	13	14	10	37
11	P11	14	14	13	41
12	P12	10	12	11	33
13	P13	14	11	12	37
$M \pm \delta$		12.6 ± 1.1	11.9 ± 1.4	11.7 ± 1.2	36.3 ± 2.8

Correlation analysis

Pearson correlation analysis revealed several statistically significant relationships at the 0.01 and 0.05 levels. Key findings include:

- Hand strength asymmetry showed a significant negative correlation with NS balance in the anticipatory reaction ($r = -0.566$, $p < 0.05$) and with SVMR reaction time ($r = -0.653$, $p < 0.05$). Positive correlations were found between hand strength asymmetry and stick rotation frequency during the 5.1-10 s interval ($r = 0.599$, $p < 0.05$), 10.1-15 s interval ($r = 0.561$, $p < 0.05$), and the total 15 s ($r = 0.646$, $p < 0.05$).
- NS balance in the anticipatory reaction displayed significant correlations with age ($r = -0.698$, $p < 0.01$), AR variability ($r = -0.584$, $p < 0.05$), hand strength asymmetry ($r = -0.566$, $p < 0.05$), and SVMR reaction time ($r = 0.767$, $p < 0.01$).
- The rotation frequency of the stick during the final 5 seconds of the 15-second dribbling-in-place test, performed under muscle fatigue conditions, showed a significant negative correlation with SVMR reaction speed ($r = -0.698$, $p < 0.01$), and positive correlations with SVMR errors ($r = 0.579$, $p < 0.05$), hand strength asymmetry ($r = 0.561$, $p < 0.05$), and total rotation frequency for 15 s ($r = 0.666$, $p < 0.05$).

These results indicate meaningful relationships among hand strength, nervous system balance, reaction speed, and the frequency of stick rotations, highlighting the interplay of physical and neurophysiological factors in elite female hockey players' performance.

InterCriteria analysis

ICrA was applied to evaluate the degree of consonance and dissonance among 16 investigated criteria describing anthropometric characteristics, anticipatory reaction, SVMR, hand strength, asymmetry, and dribbling performance (Table 4).

The ICrADa software is used for the ICrA application [6]. The obtained μ -matrix characterizes the relationships between criteria according to the predefined scale [4], where values close to 1 indicate positive consonance and values around 0.5 indicate dissonance or absence of a stable relationship.

Table 4. Notations of the defined criteria

Players		Criteria notation
Age, years		C1
Weight, kg		C2
Anticipatory reaction	s	C3
	Variability, ms	C4
	NS	C5
Simple visual-motor reaction	t, s	C6
	Variability, ms	C7
	Errors, qty	C8
Power indicators	Left hand, mm	C9
	Right hand, mm	C10
	Power, %	C11
	Dissymmetry	C12
Number of rotations during dribbling	0-5 s	C13
	5.1-10 s	C14
	10.1-15 s	C15
	Sum (qty) in 15 s	C16

The analysis revealed that the majority of relationships between the investigated indicators were located in the dissonance region ($0.25 < \mu < 0.75$). This finding indicates that the functional characteristics of female hockey players are multidimensional and that different performance domains provide relatively independent information. Only a limited number of criteria demonstrated strong positive consonance, confirming that individual components of performance cannot be described by a single physiological factor. The results in an intuitionistic fuzzy sets triangle are presented in Fig. 1.

Strong positive consonance relationships

According to the ICrA scale [4], strong positive consonance corresponds to $0.95 \leq \mu \leq 1.00$. In the obtained matrix, no relationships reached the level of strong positive consonance. However, one relationship demonstrated positive consonance: $\langle \mu, \nu \rangle_{(C9, C10)} = \langle 0.910, 0.09 \rangle$, where C9 is left hand strength and C10 is right hand strength. This represents the strongest relationship in the dataset and indicates a high degree of synchronization between bilateral strength characteristics.

The observed relationship is physiologically expected because both variables describe the same functional system. Players with higher strength capacity in one hand generally demonstrated increased strength in the opposite hand. Therefore, left and right hand strength can be considered indicators of a common latent factor related to upper-limb power development.

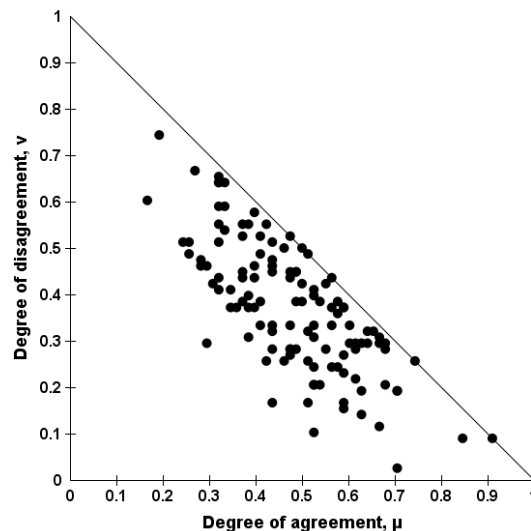


Fig. 1 ICrA results plotted on the intuitionistic fuzzy triangle

Positive consonance relationships

Positive consonance corresponds to $0.86 < \mu \leq 0.95$. Besides the bilateral strength relationship, the following relationship approached this category:

Criteria	$\langle \mu, \nu \rangle$	Interpretation
Age – AR variability (C1-C4)	$\langle 0.86, 0.09 \rangle$	Age-related similarity with anticipatory reaction variability

The relationship between age and anticipatory reaction variability suggests that age-related differences may influence the stability of anticipatory responses. However, this relationship should be interpreted cautiously because it remains below the threshold for positive consonance.

Weak positive consonance relationships

Weak positive consonance, $0.75 < \mu \leq 0.85$ was not widely observed, indicating that most variables do not show strong synchronous behaviour. The main example is:

Criteria	$\langle \mu, \nu \rangle$	Interpretation
SVMR time – NS (C6-C5)	$\langle 0.74, 0.26 \rangle$	Reaction time associated with anticipatory control

The relationship $\langle \mu, \nu \rangle_{(C5, C6)}$ indicates a moderate tendency toward similar behaviour. This suggests that some aspects of reaction regulation may share common neuromotor mechanisms.

Dissonance relationships

Most relationships were classified as dissonant $0.25 \leq \mu \leq 0.75$. This was the dominant category in the ICrA matrix. The prevalence of dissonance demonstrates that the investigated characteristics describe different aspects of hockey performance. Important examples include:

- Reaction characteristics versus strength indicators. This indicates that reaction accuracy and hand strength represent relatively independent performance dimensions. Therefore, greater muscular strength does not necessarily imply improved reaction precision.

- Strength characteristics versus rotational performance. The relationships between hand strength and dribbling indicators were mainly weak or moderate. This suggests that upper-limb strength alone does not determine technical stick-handling performance.

The finding supports the idea that hockey-specific skills depend on coordination, timing, and sensorimotor regulation rather than only force production.

Negative consonance relationships

Negative consonance, $0.05 < \mu \leq 0.25$, indicates inverse behaviour between criteria. Several weak negative consonance relationships were observed. The strongest examples were:

Criteria	$\langle \mu, v \rangle$
NS – Age (C5-C1)	$\langle 0.19, 0.74 \rangle$
Rotation 10.1-15 – SVMR time (C15-C6)	$\langle 0.17, 0.60 \rangle$
SVMR errors – NS (C8-C5)	$\langle 0.24, 0.51 \rangle$

The relationship, $\langle \mu, v \rangle_{(C15, C6)} = \langle 0.17, 0.60 \rangle$ between SVMR time and rotation frequency in the final dribbling interval represents weak negative consonance. This suggests a tendency that players with faster visual-motor responses may demonstrate different patterns of technical execution speed. However, because the value is not within the strong negative consonance interval, this relationship should be interpreted as a tendency rather than a deterministic association.

Analysis of dribbling performance indicators

The dribbling indicators (C13: rotations 0-5 s, C14: rotations 5.1-10 s, C15: rotations 10.1-15 s, C16: total rotations) showed moderate consonance relationships. The highest values were:

$$\langle \mu, v \rangle_{(C13, C16)} = \langle 0.71, 0.03 \rangle; \langle \mu, v \rangle_{(C14, C16)} = \langle 0.67, 0.12 \rangle; \text{ and } \langle \mu, v \rangle_{(C15, C16)} = \langle 0.63, 0.14 \rangle.$$

These results confirm that total rotational performance is related to the individual time intervals, but the relationship is not complete. This indicates that the temporal distribution of rotations contains additional information about technical consistency and fatigue resistance during the test.

Overall interpretation

The ICrA results demonstrate that the functional profile of female hockey players consists of several relatively independent components:

1. Upper-limb strength component, characterized by C9-C10 (left/right hand strength) with the highest consonance $\mu = 0.910$;
2. Reaction and psychophysiological component, including anticipatory reaction, visual-motor reaction, reaction errors;
3. Technical coordination component, represented by rotation frequency indicators, total dribbling performance.

These indicators demonstrate internal consistency but only moderate relationships with strength variables.

Principal component analysis

The study includes several variables that are expected to measure overlapping physiological abilities:

- Anthropometric – age and weight;

- Reaction ability – AR accuracy, AR variability, NS balance, SVMR time, SVMR variability and SVMR errors;
- Strength – left hand strength, right hand strength, strength in % and hand asymmetry;
- Technical skill – rotation 0-5 s, rotation 5.1-10 s, rotation 10.1-15 s and total rotations.

Instead of analysing 16 variables separately, PCA attempts to explain them using a few latent components (data matrix X):

$X = [\text{Age Weight NS_Balance SVMR_Time SVMR_Errors Left_Strength Asymmetry Rotation_10.1-15 Rotation_Total}]$;

The main results from the performed PCA are presented in Table 5. The PCA results are presented in the plots – Scree plot (Fig. 2), PC1-PC2 scores (Fig. 3), and loading vectors (Fig. 4). PCA was performed to reduce the dimensionality of the dataset and to identify the main latent factors responsible for the variability in anthropometric, psychophysiological, strength, and motor performance characteristics of female hockey players. The initial dataset consisted of 16 standardized variables obtained from anticipatory reaction tests, SVMR measurements, hand strength assessment, and stick-handling performance during the 15-second dribbling-in-place test. The PCA resulted in nine principal components, with the first three components having eigenvalues greater than unity according to the Kaiser criterion and explaining 78.27% of the total variance.

The second principal component (PC2) explained 17.45% of the total variance (Eigenvalue = 1.5707). In contrast to PC1, this component was characterized mainly by anthropometric and strength-related variables. The highest loadings were obtained for left hand strength (0.695) and body weight (0.633), while the remaining variables showed relatively weak contributions. Consequently, PC2 represents an anthropometric-strength factor, describing differences in physical capacity among the investigated athletes. This result confirms the expected association between body mass characteristics and absolute muscular strength, particularly in sports where upper-limb force production contributes to stick control and technical performance.

Table 5. PCA results

Eigenvalues	Explained variance, %	Cumulative variance, %
4.136	45.961	45.961
1.570	17.451	63.412
1.337	14.857	78.270
0.788	8.755	87.025
0.560	6.230	93.256
0.245	2.730	95.986
0.216	2.409	98.395
0.0975	1.084	99.479
0.0468	0.520	100.000

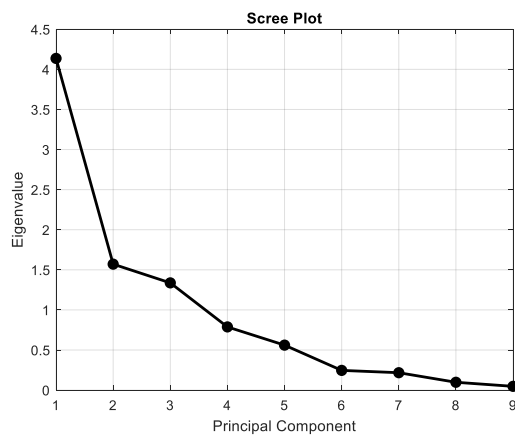


Fig. 2 PCA: Scree plot

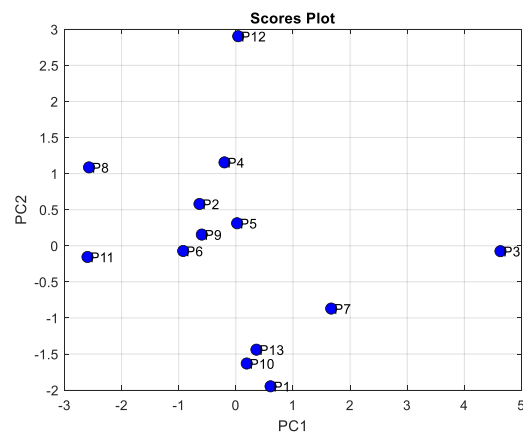


Fig. 3 PCA: PC1-PC2 scores

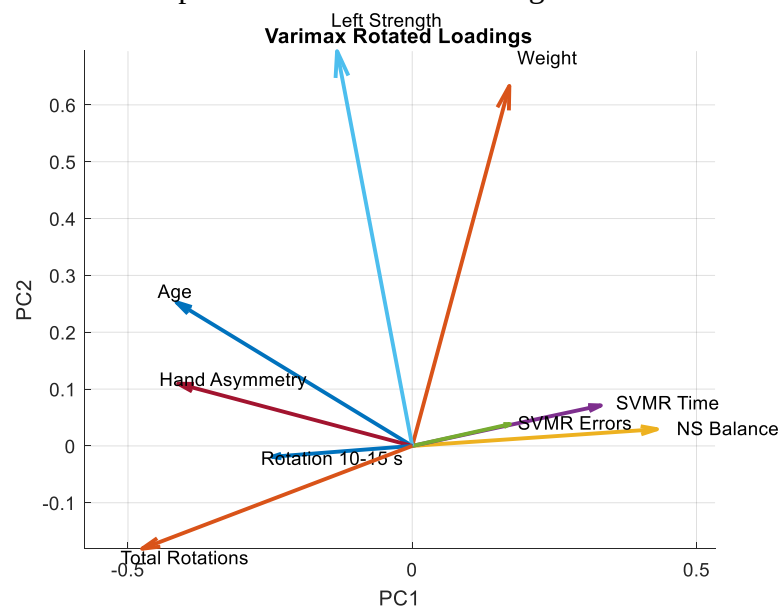


Fig. 4 PCA: loading vectors

The third principal component (PC3) accounted for 14.86% of the variance (Eigenvalue = 1.3371). The dominant contribution to this component was provided by SVMR errors (0.726), while rotation frequency during the 10.1-15 s interval also demonstrated a moderate loading (0.438). Thus, PC3 may be considered a reaction accuracy and technical consistency component, reflecting individual differences in the precision and reliability of visual-motor responses. The predominance of reaction errors in this component suggests that accuracy-related characteristics represent an independent source of variation that is not completely explained by general coordination or strength parameters.

The cumulative contribution of the first three components (78.27%) demonstrates that the complex structure of the measured performance indicators can be effectively described using a reduced set of latent variables. The remaining six components individually explained less than 9% of the variance, with eigenvalues below one, indicating a substantially lower contribution to the overall variability. Therefore, retaining three components provides an appropriate balance between information preservation and dimensionality reduction.

Overall, the PCA indicates that the performance characteristics of female hockey players are primarily determined by a general sensorimotor coordination dimension, followed by physical strength-related characteristics and reaction accuracy. The obtained three-component structure

provides a compact representation of athlete profiles and can be used for subsequent classification or clustering analysis based on functional performance characteristics.

Conclusion

The integrated application of correlation analysis, InterCriteria analysis, and principal component analysis provided a comprehensive characterization of the functional profile of female hockey players by revealing specific functional relationships, criteria interactions, and latent multidimensional structures. Correlation analysis demonstrated that older players exhibit improved anticipatory abilities with a lower delay-to-lead ratio ($r = -0.698$, $p < 0.01$), which positively correlated with SVMR time ($r = 0.767$, $p < 0.01$). Under muscular fatigue, rotational hand movements correlated negatively with reaction speed ($r = -0.698$, $p < 0.01$) and positively with reaction errors ($r = 0.579$, $p < 0.05$), highlighting the importance of maintaining fine motor control during fatigue. ICRA revealed high positive consonance between bilateral hand strength indicators ($\langle \mu, \nu \rangle = \langle 0.910, 0.09 \rangle$), while sensorimotor reaction characteristics showed predominantly dissonant relationships with anthropometric and strength parameters, confirming sensorimotor regulation as an independent functional domain. Technical coordination indicators maintained internal consistency with only moderate dependence on force production. PCA further reduced the dataset to three principal components explaining 78.27% of total variance: PC1 (45.96%) captured sensorimotor coordination and motor regulation as the primary source of variability; PC2 (17.45%) reflected anthropometric and strength parameters; and PC3 (14.86%) represented reaction accuracy and technical consistency. The convergence of these three approaches confirms that female hockey performance is a complex phenomenon driven by physical capacity, psychophysiological regulation, and technical coordination, establishing a solid methodological framework for athlete profiling, clustering, and personalized training optimization.

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