

QUESTIONNAIRE-BASED ASSESSMENT FOR MONITORING THE CONDITION OF FEMALE POLE-ACROBATICS ATHLETES: CLUSTER AND CORRELATION ANALYSES

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ABSTRACT

Background. Monitoring the functional state of athletes undergoing intense asymmetric loads, as in pole acrobatics, traditionally relies on comprehensive instrumental assessments (dynamometry, bioimpedance, electromyography) that must be repeated several times. However, these methods are expensive, time-consuming, and poorly suited for frequent use, especially during rehabilitation for identified dysfunctions or injuries. This necessitates the development of accessible and reliable tests.

Aim. To determine the validity of replacing repeated instrumental studies of athletes' functional state (electrophysiological, strength, visual) with a questionnaire during their rehabilitation.

Materials and Methods. A retrospective analysis of archival data from 20 female pole acrobatics athletes (aged 23–40 years) was conducted. The analysis included 58 instrumental parameters from previous studies (dynamometry, bioimpedance analysis, surface and stimulation electromyography, photogrammetry) and 50 questionnaire responses. Due to the non-normal distribution of the data, non-parametric methods were applied: hierarchical cluster analysis (Ward's method) and Spearman's rank correlations. The cluster analysis grouped the questionnaire items and instrumental parameters into five meaningful domains that fully corresponded to the instrumental constructs: strength indicators, body morphology, postural symmetry, neuromuscular activation, and neuromuscular excitability.

Results. Within the clusters, fifteen stable and strong correlations were identified ($|r|=[0.60–0.88]$; $p<0.05$), which demonstrates the high convergent validity of the questionnaire. The most informative items were found to be Nos.25, 48, 49 (for strength); Nos.27, 23 (for body composition); Nos.1, 2 (for posture); Nos.20, 29 (for surface EMG); and Nos.41, 40 (for stimulation EMG).

Conclusions. The developed questionnaire captures variations in key physiological indicators and can replace repeated instrumental assessments when monitoring the condition of female athletes' post-rehabilitation.

Keywords: *bioimpedance analysis, surface and stimulation electromyography, postural indices, strength imbalance.*

Abbreviations

%FAT – Percentage of Fat And Tissue.

A/F – Amplitude/Frequency ratio.

ATSI – Anatomical Transverse Section Index.

BMR – Basal Metabolic Rate.

CMAP – Compound Muscle Action Potential.

EMG – ElectroMyoGraphy.

FAI – Frontal Asymmetry Index.

FFM – Fat-Free Mass.

HDI – Height Difference Index.

POTSI – Posterior Overall Trunk Shift Index.

RPE – Rating of Perceived Exertion.

TBW – Total Body Water.

Introduction

Pole acrobatics is a coordinatively complex sports discipline that combines elements of gymnastics, acrobatics, and dance [1–6]. It places unique demands on the physical fitness of athletes, requiring simultaneous display of high levels of static and dynamic strength, flexibility, and specific endurance [7; 8]. Due to its biomechanical complexity and the load on the musculoskeletal

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system, it is often compared to Olympic sports such as artistic gymnastics, particularly exercises on the parallel bars and rings [3; 9–12].

A key feature that distinguishes pole acrobatics is the pronounced asymmetrical nature of the loads [6; 13]. During training and competitions, athletes systematically use the dominant side of the body to perform pulling and holding elements, while the non-dominant side more often serves a supportive function [6]. Such a chronic, unilateral nature of training stimuli is a powerful factor leading to specific adaptive changes in the body. This phenomenon is well-studied in other asymmetrical sports, such as tennis, fencing, baseball (especially in pitchers), and many martial arts [14–22]. Long-term asymmetrical loads can lead not only to morphofunctional specialization but also to the formation of persistent muscle imbalances, which, in turn, are considered one of the leading risk factors for overuse injuries [23–26].

Our previous research, which forms the basis for this study, was dedicated to a comprehensive analysis of these adaptive processes [13; 27–30].

We quantitatively documented that long-term practice of pole acrobatics leads to multifaceted changes:

1) *morphological*, when a local increase in muscle mass and thickness was observed on the dominant side of the body, which is a direct structural reaction to a specific load;

2) *functional*, when a significant strength imbalance was found between the right and left limbs, reaching up to 12% in some athletes and persisting even after many years of training;

3) *neuromuscular*, when, using EMG, we recorded stable differences in the patterns of bioelectrical activity in paired muscles, indicating a long-term adaptation of the central nervous system to asymmetrical motor tasks;

4) *postural*, within which visual and photogrammetric screening revealed the presence of persistent postural deviations (e.g., asymmetry in shoulder height), which is reflected in specialized indices such as HDI and FAI.

Traditionally, an entire arsenal of instrumental methods, considered the "gold standard" in sports science, is used for the objective assessment of these parameters [31–33]. This includes dynamometry for measuring strength, bioimpedance analysis for body composition, surface EMG for assessing muscle activation, and photogrammetry for posture analysis [34–38]. Despite their high accuracy, this approach has significant limitations: it is expensive, requires specialized equip-

ment and qualified personnel, and the assessment of a single athlete can be very time-consuming [39–42]. This makes instrumental methods poorly suited for frequent, routine monitoring, especially during rehabilitation from injuries, where continuous tracking of recovery progress is crucial.

In response to these challenges, sports science is actively seeking simpler, more accessible, and cost-effective monitoring tools. Questionnaires and surveys have long been successfully used to assess subjective aspects of an athlete's condition [43–47]. Numerous studies confirm a high correlation between athletes' subjective ratings (e.g., the Rating of Perceived Exertion scale) and objective physiological markers [48–51]. Questionnaires are effectively used for monitoring overtraining, stress, and recovery. However, most existing questionnaires are focused on assessing general condition and do not account for the specific asymmetrical changes that are a key issue in pole acrobatics [52–54].

The **aim** of the study was to determine the validity of replacing repeated instrumental studies of the functional state of athletes (electrophysiological, strength, visual) during their rehabilitation with questionnaire questions.

Materials and Methods

This study employed a retrospective correlational design based on the analysis of a pre-existing dataset. No new instrumental measurements were conducted at the current stage of work. The analysis included archival data from 20 professional female pole acrobatics athletes, aged 23–40 (mean age was $[33.5 \pm 10.5]$ years), who had muscle and postural asymmetries identified during the study. These asymmetries were not accompanied by any pain sensations other than fatigue from intensive training. All participants had at least 18 months of systematic training and, at the time of the initial assessment, mean training experience – $[6.7 \pm 4.9]$ years, had no acute injuries that could affect the results. These and other characteristics of female athletes are shown in *Table 1*.

The dataset used included the results of a questionnaire and five instrumental methods: bioimpedance analysis, dynamometry, photogrammetry, and surface and stimulation electroneuromyography. These methods were applied to measure parameters of posture, symmetry, and strength, which are detailed in the authors' previous publications.

1. Assessment of neuromuscular excitability.

The first step in assessing the athletes' functional state was the evaluation of peripheral nerve

Table 1. Characteristics of the study group

Characteristic	Value
Age, years	33.5±10.5
Training experience, years	6.7±4.9
Body mass, kg	59.1±10.4
Weekly training time, min	384±216
Stature, cm	168.5±18.5

conduction using stimulation myography with the Neuro-MEP-Micro system (DX Systems, Ukraine). This method allowed for the identification of baseline nervous system characteristics that underlie muscle function. The procedure involved stimulating nerves at the wrist and elbow to record the Compound Muscle Action Potential (CMAP). Key parameters such as latency, amplitude, and potential area were evaluated, enabling the detection of initial signs of asymmetry in functional activity between the right and left arms. The results, method, and features of its application are described in [13].

2. Assessment of neuromuscular activation.

Next, for a more in-depth analysis of muscle function, their bioelectrical activity was examined using an 8-channel surface electromyography (sEMG) system (Neurosoft, Ukraine). Signals were recorded from 12 paired muscles of the trunk and shoulder girdle, both at rest and during standardized functional tests that mimicked specific movements from pole acrobatics. Analysis of the peak amplitude ($A_{\max}$) and the integral amplitude/frequency ratio (A/F) helped identify patterns of muscle imbalance and compensatory mechanisms developed through training. Publication [28] describes the results, method, and features of its application.

3. Body composition analysis.

To understand how functional asymmetries relate to structural changes, a body composition analysis was performed using the segmental bio-impedance analyzer Tanita MC-780 MA (Tanita Corp., Japan). This method allowed not only for the determination of general indicators like %FAT and FFM but also for a detailed assessment of the distribution of these components and the electrical impedance for each arm, leg, and the trunk separately. The results confirmed the presence of structural differences between the right and left sides of the body, indicating an uneven distribution of loads. For a detailed description of the results, method, and application, see publication [27].

4. Strength assessment.

The next logical step was the quantitative assessment of strength, as it is the final outcome of neuromuscular and structural organization. For this, the dynamometric system Back-Check 607 (Dr. Wolff, Germany) was used. The protocol included eight standardized static tests that modeled key movements in pole acrobatics, particularly lateral trunk flexions and various types of arm movements. This approach provided objective data on the peak and average force for the right and left sides, which was crucial for testing the hypothesis of strength asymmetry. A detailed account of the results, methodology, and specifics of its application is provided in publication [30].

5. Postural assessment.

The final stage of the instrumental diagnostics was a comprehensive analysis of postural symmetry using the photogrammetric system APECS-Clinic (Saneftec, France). This visual screening integrated all previous data to assess how the identified neuromuscular, structural, and strength characteristics manifest in the athlete's overall posture. The system automatically calculated several objective asymmetry indices, such as HDI, FAI and POTSI, providing a holistic picture of postural balance. The results of the study, the methodology used, and the specifics of its application are detailed in publication [29].

Each athlete completed a specially designed 50-item questionnaire aimed at the subjective assessment of their functional state and perception of asymmetry (see Fig. 1).

For statistical data processing, hierarchical cluster analysis, Ward's method with Euclidean distance as the measure of dissimilarity, was applied. The purpose of this stage was to group variables (instrumental and questionnaire-based) into meaningful groups, or clusters, that would reflect key physiological domains (e.g., "strength", "morphology", "posture", etc.).

Within each identified cluster, Spearman's rank correlation coefficient (ρ) was used to assess the strength and direction of the relationship between subjective responses and objective indicators. Associations were considered statistically significant at $|\rho| \geq 0.60$ with a significance level of $p < 0.05$ for a sample size of $n = 20$. This threshold ($|\rho| \geq 0.60$) was chosen to highlight only the strongest and most practically significant relationships.

The Statistica 10.0 (Statsoft, USA) was used for statistical data processing. In total, 58 instrumental variables and 50 questionnaire scores for each of the 20 participants were included in the analysis.

Functional-status assessment questionnaire for female pole-acrobatics athletes

Before you begin, identify and remember which side of your body is dominant. The dominant arm is the one you normally use for pulling, hanging, pull-ups, or actively controlling a pole element. The dominant leg is the leg on the same side as the dominant arm. The non-dominant arm is regarded as the supporting arm. All subsequent questions refer to differences between the dominant and non-dominant arms.

Instructions: rate each statement on a scale from 1 to 10, where:

1 = not felt at all ... 10 = felt very strongly / constantly / clearly.

1. I feel that one shoulder is positioned higher than the other.
2. I notice a tilt of the torso toward the dominant or non-dominant side.
3. I experience greater load on one leg during prolonged standing.
4. During symmetrical elements my body feels asymmetrically controlled.
5. My back appears more arched or flattened on one side.
6. In a passive hang I maintain balance better with one side.
7. I sense that one side of the trunk is more involved in stabilization.
8. Post-exercise soreness occurs more often in the dominant-shoulder region.
9. The back on the dominant side feels tighter or denser.
10. One arm has a superior ability to support or push.
11. Back muscles fatigue more on one side.
12. In static exercises one arm tires more quickly.
13. In strength movements one side activates more strongly and assumes a larger share of the load.
14. I rely more on one arm for balance.
15. In prolonged static poses one side controls the position better.
16. After exercises with symmetrical loading fatigue is perceived on one side.
17. During an exercise the muscles do not always respond immediately, and I do not feel their activation.
18. During transitions between movements one arm reacts more slowly.
19. At times one side of the muscles activates with a delay or shows a slowed response.
20. Touch or support with one hand feels less distinct.
21. Under load one arm engages with a noticeable delay.
22. In backbends or bridges one side of the trunk feels more flexible.
23. I perceive a greater volume or weight of muscles on one side.
24. When performing tricks one arm or leg tolerates the load better.
25. My non-dominant arm always activates better during elements requiring a supporting function.
26. I feel reduced control of trunk stability on one side.
27. In weight-bearing leg positions one leg controls movement less effectively.
28. After training, the muscles on one side feel more "pumped" or heavier.
29. Transitions between elements are easier on one side.
30. When balance is lost I compensate more frequently with one side.
31. In prolonged static poses one side controls the position better.
32. After exercises with symmetrical loading fatigue is perceived on one side.
33. When looking in a mirror, one clavicle appears noticeably higher than the other.
34. I sense that the pelvis "sags" more on one side.
35. I observe that the ribs protrude asymmetrically on the left and right.
36. In forward flexion one side of the spine bulges more.
37. Mild tingling appears sooner in one arm after hanging.
38. After a brief skin contact the sensation subsides more slowly on one side.
39. During rapid grip changes one hand responds more weakly.
40. Sometimes the signal to the muscles of one leg arrives with a delay.
41. During dynamic combinations one side of the back begins to tremble sooner.
42. In isometric holds the scapula on one side pulses unpleasantly.
43. During a quick transition from hang to support one pectoral muscle contracts more noticeably.
44. I feel spasms only on one side of the lower back after leg raises.
45. One leg feels "heavier" after prolonged sitting.
46. In handstands I feel greater muscle tension in one arm.
47. During a handstand it is easier to keep balance toward the dominant side.
48. After an intense workout, either the left or the right pectoral muscle feels bulkier.
49. During asymmetric elements involving pulling and support one arm loses stability more quickly.
50. During a rapid lift into an element one arm moves less synchronously or more slowly.

Fig. 1. Questionnaire for self-assessment of functional asymmetries.

In the first stage, all variables were tested for normality of distribution using the Shapiro-Wilk test. The results showed that the distribution of all indicators was significantly different from normal ($W=[0.81-0.96]$; $p<0.05$). This justified the need to use non-parametric, "distribution-free" statistical methods.

The study was conducted in compliance with the ethical standards and principles of the Declaration of Helsinki. All participants signed an informed consent to participate in the study.

Results

The developed questionnaire is intended to become a reliable and valid alternative to comprehensive instrumental assessment, allowing for quantitative demonstration that athletes' subjective responses reliably reflect objective changes in their bodies. This opens the prospect of creating a scientifically validated, shortened version of the questionnaire that can be used for frequent, inexpensive, and effective monitoring, which is particularly important during rehabilitation and for injury prevention.

To do this, we used a popular two-stage statistical approach [55–58]. First, using cluster analysis, we grouped the objective and subjective data into meaningful clusters to verify whether the questionnaire items correspond to key physiological constructs (strength, morphology, etc.). Then, within each cluster, we calculated Spearman's rank correlations between each question and its

corresponding instrumental parameter to assess the strength and significance of their relationship. This approach, in full or in part, has been previously used in a number of studies that have demonstrated its validity [43; 56; 59]. Such a study design [43; 60–63] allows us not just to assume, but to quantitatively demonstrate that the subjective responses of athletes reliably reflect objective changes in their bodies. This opens the prospect of creating a scientifically validated, shortened version of the questionnaire that can be used for frequent, inexpensive, and effective monitoring, which is particularly important for rehabilitation and injury prevention [64–67].

The primary task of our analysis was to understand if an internal logical structure exists within the dataset, which combined objective instrumental parameters and the subjective responses of the athletes. For this, we applied hierarchical cluster analysis, a statistical method that allows for the grouping of variables based on their similarity.

The results of the analysis, presented as dendrograms (Figures 2–6), revealed five distinct and meaningfully interpretable clusters. Importantly, these clusters naturally grouped the instrumental parameters with their corresponding questionnaire items by content (Table 2).

This served as the first significant piece of evidence that the questionnaire measures the same physiological constructs as the instrumental methods.

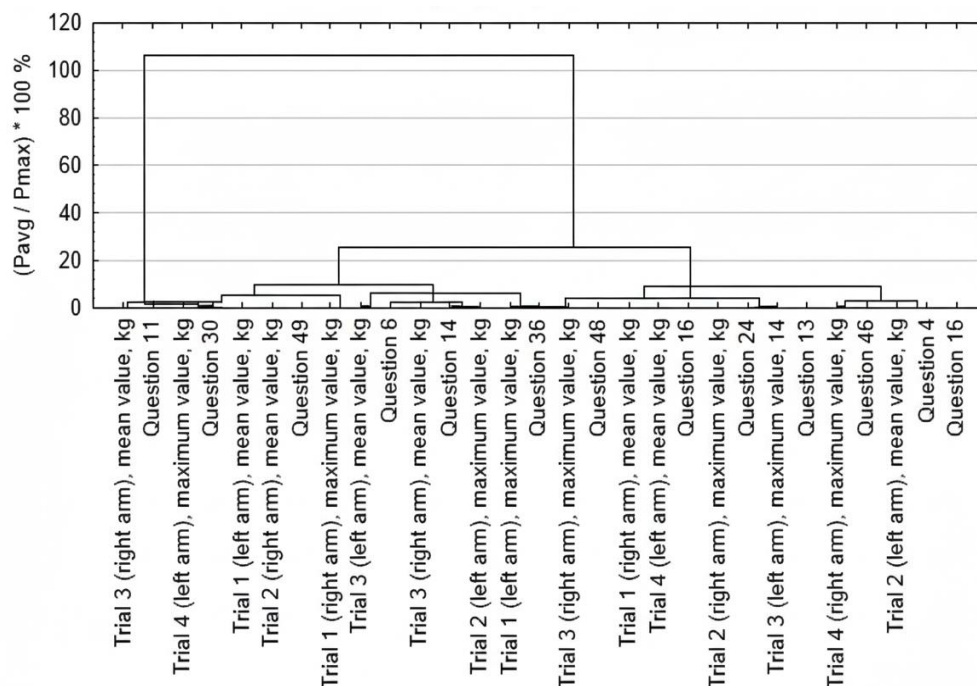


Fig. 2. Cluster 1 (Strength metrics, Back-Check).

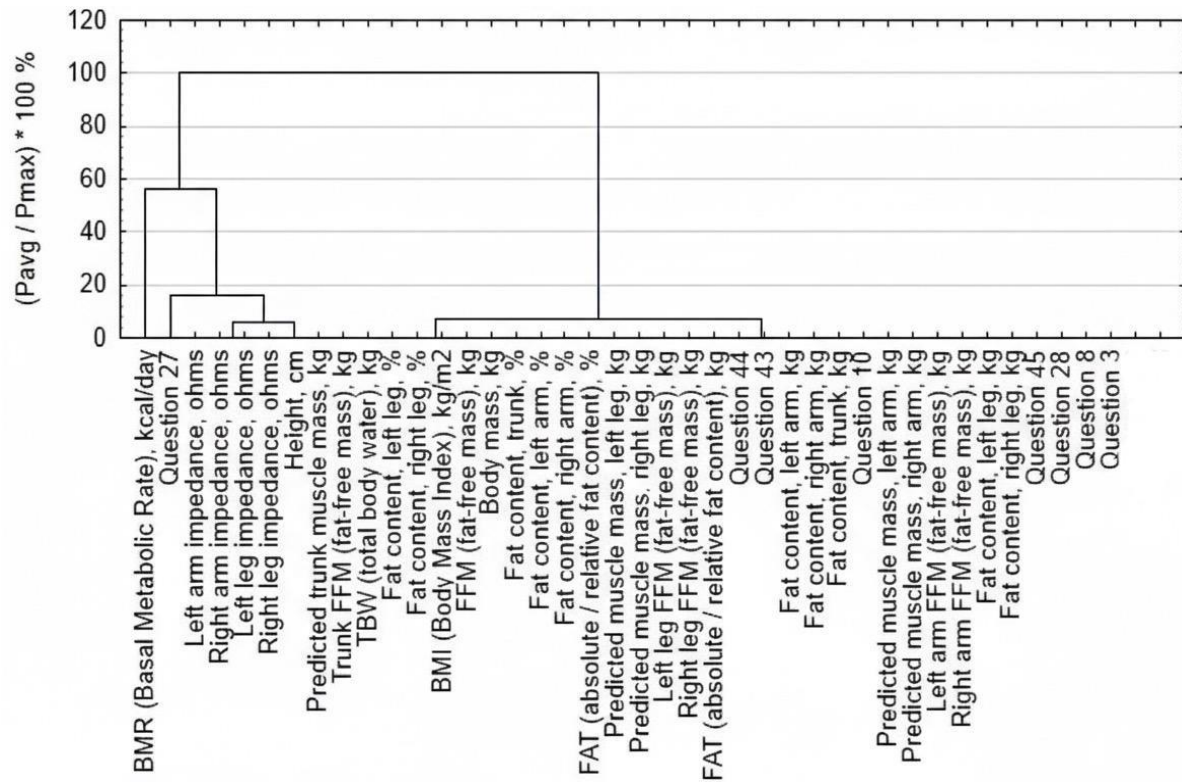


Fig. 3. Cluster 2 (Body composition, Tanita).

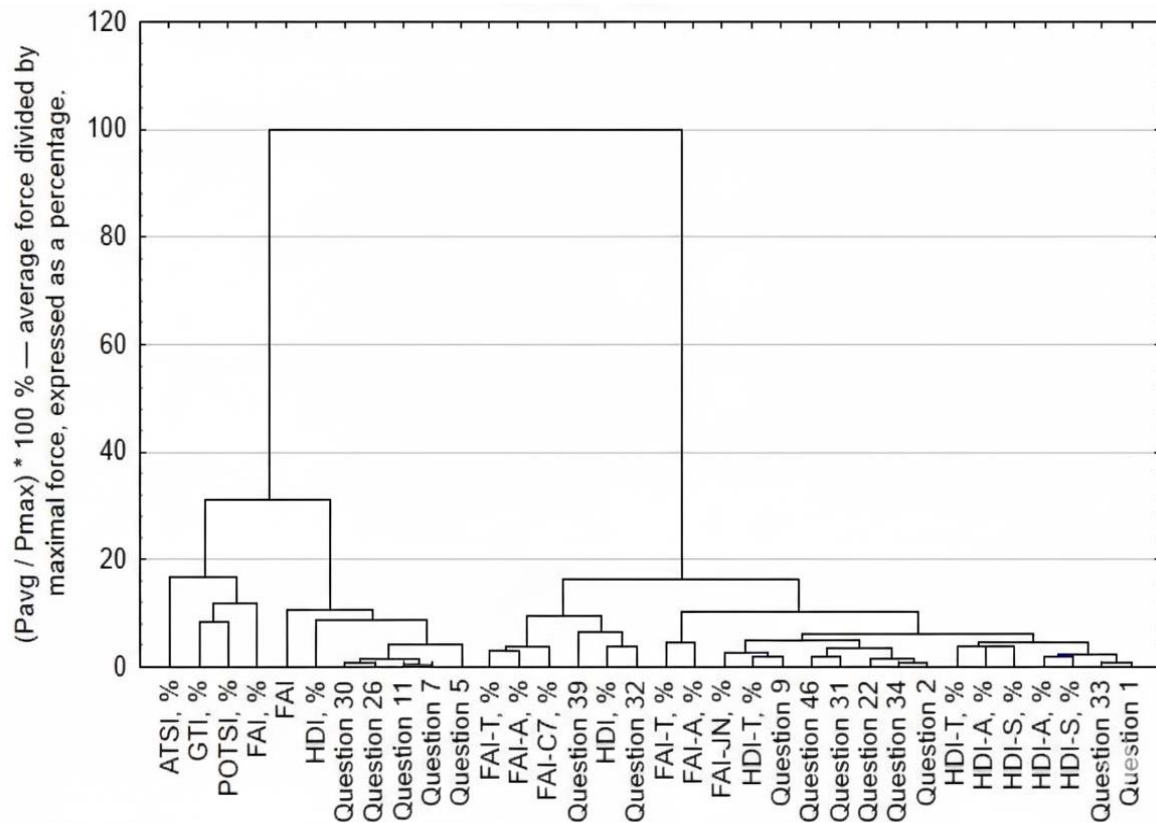


Fig. 4. Cluster 3 (Postural symmetry, visual screening).

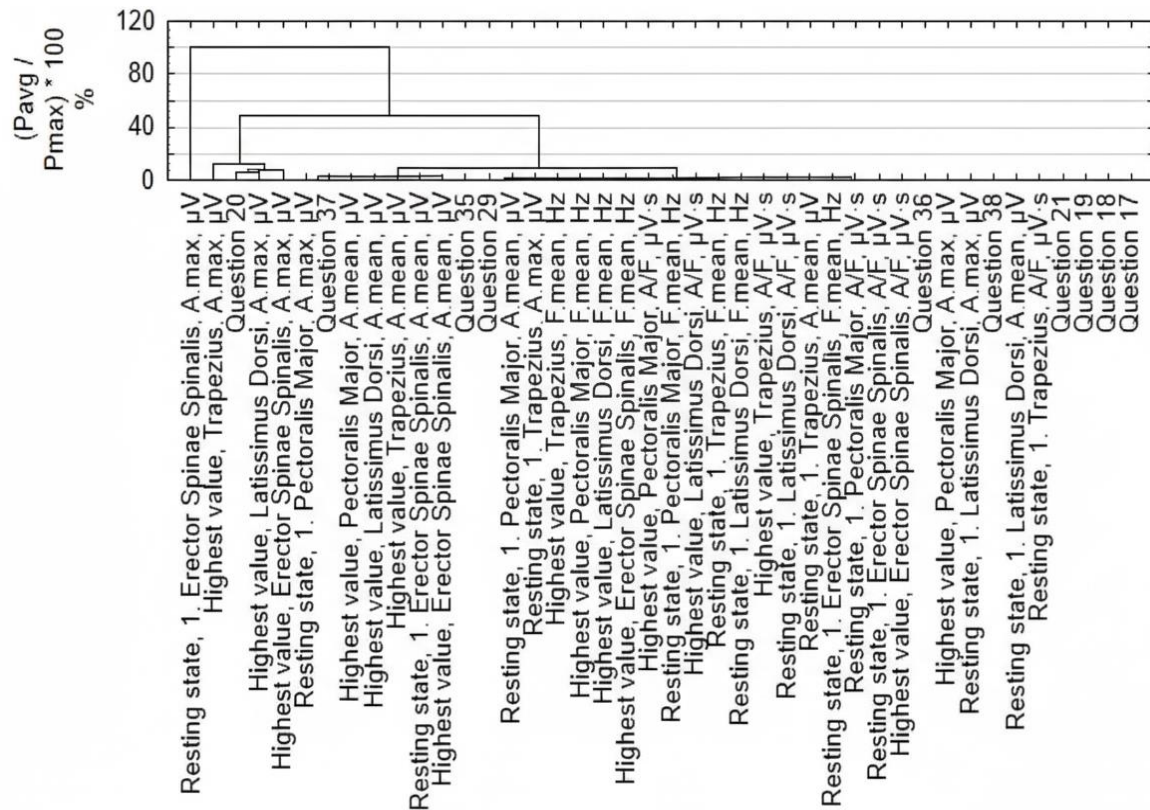


Fig. 5. Cluster 4 (Neuromuscular activation, surface EMG).

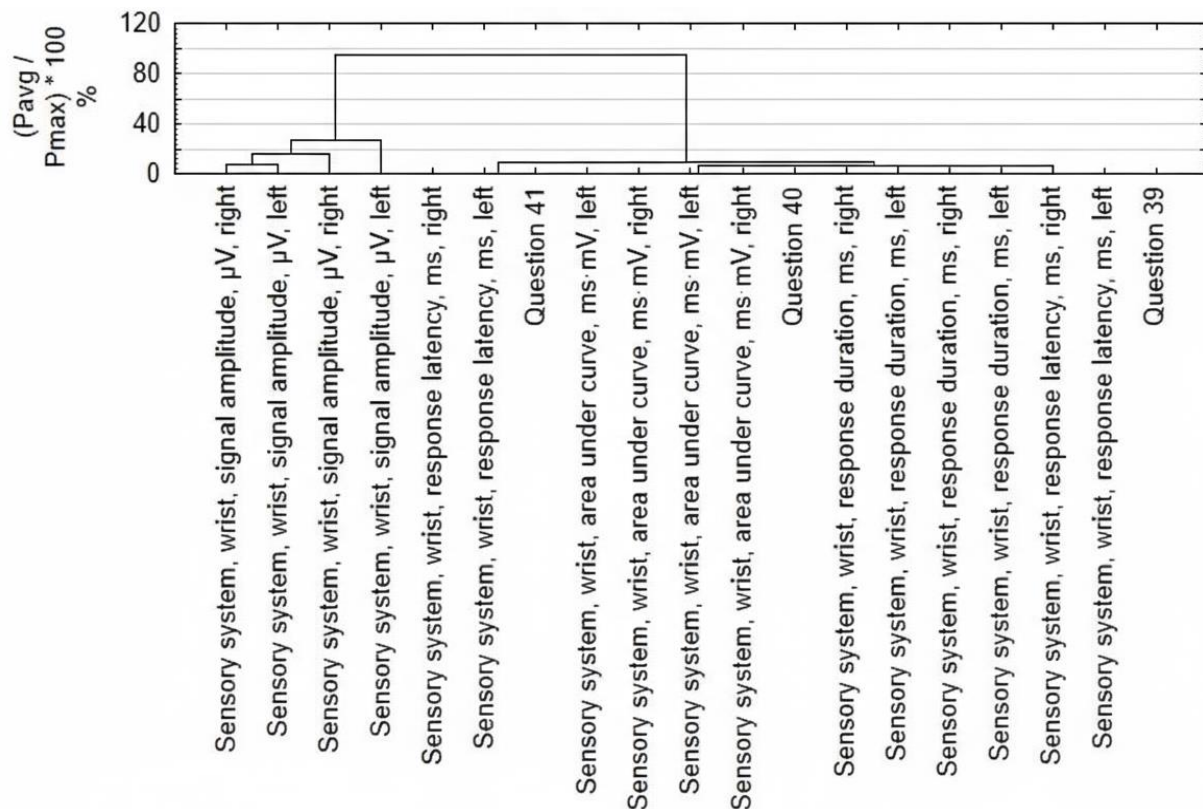


Fig. 6. Cluster 5 (Neuromuscular excitability, stimulation myography)

Table 2. Cluster structure obtained from hierarchical analysis and the corresponding indicative questionnaire items

No.	Cluster	Key variables	Indicative questionnaire items
1	Strength metrics (Back-Check)	Maximum / mean force in 8 trials	4, 6, 25, 48, 49
2	Body composition (Tanita)	Body mass, BMR, TBW, %FAT, segmental impedance	10, 23, 27, 44
3	Postural symmetry (visual screening)	HDI-S, HDI-A, FAI-A/C7, ATSI, POTSI	1, 2, 5, 32, 46
4	Neuromuscular activation (surface EMG)	A/F index and $A_{\max}$ of m. trapezius, m. latissimus dorsi, m. pectoralis muscles	20, 29, 35, 37
5	Neuromuscular excitability (stimulation myography)	Latency, amplitude, and area of the CMAP at the wrist	40–42

The formed clusters were named according to the nature of the variables they contained:

Cluster 1 "Strength Indicators" combined the results of the Back-Check dynamometry and questionnaire items related to the subjective perception of strength and strength imbalance (items 4, 6, 25, 48, 49).

Cluster 2 "Body Composition" included data from the bioimpedance analysis (body mass, % fat, segmental impedance) and questions reflecting the perception of one's own anthropometric data (items 10, 23, 27, 44).

Cluster 3 "Postural Symmetry" grouped objective postural asymmetry indices obtained from the visual screening and questionnaire items describing the sensation of trunk tilt and shoulder girdle asymmetry (items 1, 2, 5, 32, 46).

Cluster 4 "Neuromuscular Activation" combined surface EMG parameters (activity of the trapezius, latissimus dorsi, and pectoral muscles) and questions related to the sensation of muscle tone and fatigue (items 20, 29, 35, 37).

Cluster 5 "Neuromuscular Excitability" included parameters from stimulation myography (latency and amplitude of CMAP) and questions concerning muscle reaction speed and sensory perceptions (items 40–42).

Thus, the cluster analysis confirmed our initial hypothesis: the developed questionnaire possesses high construct validity, as its internal structure fully replicates the logic of a comprehensive instrumental assessment.

The next step was to determine not just the presence but also the strength of the relationship between subjective ratings and objective data within each cluster. For this, we calculated Spearman's rank correlation coefficients. The analysis revealed

a series of statistically significant and strong correlations, which confirmed the high convergent validity of the questionnaire. The most indicative and informative relationships are presented in Table 3.

In the strength cluster (Cluster 1), very high positive correlations were found. For example, responses to item 48 ("After an intense workout, either the left or the right pectoral muscle feels bulkier") had a correlation coefficient of $\rho=0.80$ with the objective measure of right-arm strength in the lateral abduction test. Item 25 ("My non-dominant arm always activates better during elements requiring a supportive function") also strongly correlated with right-arm strength ($\rho=0.79$). This directly indicates that the athletes' subjective feelings about the strength and function of their arms reliably reflect the real, instrumentally measured strength imbalance.

In the body composition cluster (Cluster 2), item 27 ("In positions supported by the legs, one leg has worse motor control") showed an extremely high correlation with objective body mass ($\rho=0.82$). Strong negative correlations were also found: for instance, item 10 ("One arm has a more developed ability for support and push-off") was closely related to the electrical impedance of the left leg ($\rho=-0.79$). This suggests that athletes are capable of subjectively assessing not only their overall mass but also specific features of their body composition that affect bioimpedance parameters.

In the postural cluster (Cluster 3), the highest coefficients in the entire study were obtained. Item 1 ("I feel that one shoulder is higher than the other") demonstrated a very high correlation with the vertical shoulder asymmetry index HDI-S ($\rho=0.88$).

Table 3. Selected highest Spearman rank correlations within clusters (<0.05)

Cluster	Questionnaire item	Instrumental metric	ρ (Spearman)
1	25	Trial 1 (right), kg	0.79
	48	Trial 4 (right), kg	0.80
	49	Trial 2 (left), kg	0.70
2	27	Body mass, kg	0.82
	23	BMR, kcal $\times$ day ⁻¹	0.77
	10	Impedance, left leg, Ω	-0.79
	44	FAT, %	-0.67
3	1	HDI-S, %	0.88
	5	HDI-A, %	0.76
	2	FAI-A, %	0.74
4	20	A/F m. latissimus (rest)	-0.87
	29	A/F m. pectoralis (load)	-0.86
	35	A/F m. pectoralis (rest)	0.79
5	41	Latency (wrist R), ms	0.71
	40	CMAP amplitude (wrist R), μ V	-0.62

Notes: all listed correlations are statistically significant; only the most informative pairs are shown;

Trials 1, 2 and 4 – static-dynamometry positions in the Back-Check test:

- Trial 1 – trunk lateral flexion;
- Trial 2 – arm flexion in pronation;
- Trial 4 – lateral abduction in supination;
- kg – kilograms, absolute force;
- BMR – Basal Metabolic Rate, kcal $\times$ day⁻¹;

Ω – ohms, electrical impedance of the body segment in bioimpedance analysis;

FAT % – percentage Body-Fat Content;

HDI-S – Height Difference Index – Shoulders (vertical difference between shoulder points);

HDI-A – Height Difference Index – Axillae (vertical difference between axillary points);

FAI-A – Frontal Asymmetry Index – Axillae (frontal trunk asymmetry at axillary level);

A/F – Amplitude-to-Frequency ratio (integrated EMG amplitude $\div$ mean frequency);

m. latissimus / m. pectoralis – musculus latissimus dorsi / musculus pectoralis major;

Latency – time from electrical stimulus to CMAP onset, ms;

ms – milliseconds;

μ V – microvolts.

This is an extremely important result, showing that a simple questionnaire item can, with high accuracy, replace the complex procedure of photogrammetric analysis for a screening assessment of posture.

In the neuromuscular activation and excitability clusters (*Clusters 4 and 5*), strong relationships were also identified. For example, item 20 ("Touch or support with one arm is less 'perceptible'") was strongly negatively correlated with the activity of the latissimus dorsi muscle at rest (A/F, $\rho=-0.87$). This means that the lower the subjective sensitivity, the higher the objective muscle activity, which may indicate chronic tension.

Therefore, the high correlation coefficients obtained (ranging from $|\rho|$ of 0.62 to 0.88) within each cluster provide compelling evidence that the developed questionnaire can accurately capture variations in objective parameters. This justifies its potential use as a standalone tool for monitoring the condition of athletes. Thus, the questionnaire enables effective regular monitoring of athletes' condition without complex equipment.

Based on the results of the cluster analysis, the most significant questions of the questionnaire were identified and an abbreviated version of the questionnaire was proposed as part of the most important questions (*Fig. 7*).

Questionnaire for Self-Assessment of Functional Asymmetries*Cluster 1: Strength Indicators*

1. (No.25) My non-dominant arm always activates better during elements requiring a supporting function.
2. (No.48) After an intense workout, either the left or the right pectoral muscle feels bulkier.
3. (No.49) During asymmetric elements involving pulling and support one arm loses stability more quickly.

Cluster 2: Body Composition (Morphology)

4. (No.27) In weight-bearing leg positions one leg controls movement less effectively.
5. (No.23) I perceive a greater volume or weight of muscles on one side.
6. (No.10) One arm has a superior ability to support or push.
7. (No.44) I feel spasms only on one side of the lower back after leg raises.

Cluster 3: Postural Symmetry (Posture)

8. (No.1) I feel that one shoulder is positioned higher than the other.
9. (No.5) My back appears more arched or flattened on one side.
10. (No.2) I notice a tilt of the torso toward the dominant or non-dominant side.

Cluster 4: Neuromuscular Activation (Surface EMG)

11. (No.20) Touch or support with one hand feels less distinct.
12. (No.29) Transitions between elements are easier on one side.
13. (No.35) I observe that the ribs protrude asymmetrically on the left and right.

Cluster 5: Neuromuscular Excitability (Stimulation EMG)

14. (No.41) During dynamic combinations one side of the back begins to tremble sooner.
15. (No.40) Sometimes, the signal to the muscles in one of my legs arrives with a delay.

Fig. 7. Questionnaire for Self-Assessment of Functional Asymmetries (Shortened Version)

Discussion

The main objective of this study was to develop and validate a specialized questionnaire that could serve as an effective and cost-efficient alternative to expensive instrumental monitoring of the functional state of female pole acrobatics athletes. The results obtained are compelling and open new prospects for the practical application of this tool in sports medicine and rehabilitation.

The central finding of our study is the empirical validation that the subjective feelings of athletes, captured by the questionnaire, are grounded in a strong objective basis. This conclusion is supported by extensive reviews showing that subjective self-reports often reflect acute and chronic training loads with greater sensitivity and consistency than many objective instrumental measures [43]. Studies demonstrate that well-designed questionnaires are not just a low-cost alternative but are also a reliable independent tool for monitoring [61]. The cluster analysis procedure clearly grouped 108 variables into five meaningful domains that fully replicated the logic of a comprehensive instrumental assessment. This indicates the high construct validity of the questionnaire: its items genuinely measure the physiological aspects (strength, morphology, posture, etc.) they were designed to evaluate.

The results of the correlation analysis, in turn, demonstrated high convergent validity. The strong correlations identified, particularly the significant coefficient of $\rho=0.88$ between the question about shoulder asymmetry and the objective HDI-S index, are extremely important. They show that a well-formulated question can serve as a reliable and accurate proxy marker for a parameter that typically requires specialized photogrammetric equipment to measure. Similar strong relationships were found in other domains, confirming that the questionnaire reliably captures variations in all key physiological areas affected by asymmetric loads.

The findings have significant practical implications. The proven validity of the questionnaire allows it to be recommended for several tasks:

1. *Effective monitoring during rehabilitation.* Instead of conducting multiple expensive instrumental assessments to track recovery progress, coaches and physical therapists can use the questionnaire at practically no cost. This allows for more frequent and prompt data collection without significant expense, thereby improving control over the rehabilitation process.

2. *Screening and early diagnosis.* The questionnaire can be used as a primary screening tool to identify at-risk athletes with pronounced asymmetries. Exceeding certain threshold values on the

questionnaire can serve as a signal to conduct a more in-depth instrumental assessment.

3. *Optimization of the training process.* Regular administration of the questionnaire allows for tracking the body's response to training loads and timely adjustment of the program to prevent the worsening of imbalances.

The study was **limited** to a small sample size ($n=20$), which did not reveal strong correlations. Furthermore, the study was focused exclusively on a female sample of pole acrobatics athletes. Further validation of the questionnaire in other populations, particularly males, is necessary, as is its adaptation and testing for effectiveness in other asymmetric sports.

Conclusions

This study led to the development and validation of a specialized questionnaire for monitoring the functional state of female athletes in pole acrobatics.

1. It was demonstrated that the 50 questionnaire items, through cluster analysis, group into five meaningful domains: strength balance, body composition, postural symmetry, neuromuscular activation, and neuromuscular excitability. This structure fully corresponds to the five areas of a comprehensive instrumental assessment, confirming the high construct validity of the questionnaire.

2. Spearman's rank correlation analysis revealed 15 stable and strong relationships ($|r|=[0.60-0.88]$; $p<0.05$) between the questionnaire responses and objective instrumental parameters. This indicates the high convergent validity of the tool: the athletes' subjective assessments reliably reflect their actual functional state.

3. Based on the analysis, the most informative items for each domain were identified. This allows for the use of a shortened, 15-item version of the questionnaire for rapid monitoring without compromising its prognostic value.

4. The high validity indicators support the conclusion that repeated comprehensive instrumental

assessment when monitoring rehabilitation progress can be entirely replaced by the questionnaire. Instrumental methods should be reserved for cases where the questionnaire results indicate critical deviations from the norm.

Thus, the developed questionnaire is a reliable, valid, and cost-effective tool that can be recommended for wide implementation in the practice of sports medicine and physical therapy.

Our **future research** will focus on investigating the posture, symmetry, and muscle strength of pole-acrobatics athletes with the use of the shortened 15-item questionnaire.

DECLARATIONS

Disclosure Statement

The authors declare that there is no conflict of interest that could have influenced the study's results.

Data Transparency

All data generated during the study can be made available upon reasonable request from the corresponding author.

Ethics Statement

No ethical standards were violated in the course of this research. All participants took part voluntarily on a volunteer basis and provided written informed consent.

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Consent for Publication

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