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Adaptive Skin Changes in Paralympic Athletes: Clinical Evaluation and Phenotype-Based Corrective Approaches

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Abstract: Adaptive skin changes in Paralympic athletes represent a significant yet underexplored area in dermatology. Continuous exposure to mechanical pressure, friction, occlusion, and prosthetic devices leads to specific dermatological conditions that differ from those observed in able-bodied athletes. This study aimed to evaluate the clinical and functional characteristics of adaptive skin changes and to develop phenotype-based corrective approaches.A cross-sectional study involving 120 Paralympic athletes was conducted using clinical examination, dermoscopy, transepidermal water loss (TEWL), and ultrasound imaging. Hyperkeratosis (72%), irritant dermatitis (65%), and maceration (38%) were the most common findings. TEWL values were significantly elevated in affected areas, indicating impaired barrier function.The results demonstrate that adaptive dermatoses are multifactorial and require individualized correction strategies based on clinical phenotype.

Keywords: Paralympic athletes; dermatology; adaptive dermatoses; hyperkeratosis; TEWL; skin barrier; sports medicine.

Introduction: The skin is a highly dynamic and adaptive organ that plays a critical role in maintaining homeostasis and protecting the body from external environmental, mechanical, and biological stressors. As the first line of defense, the skin continuously responds to various physical stimuli by undergoing structural, functional, and biochemical modifications. These adaptive responses are particularly pronounced under conditions of chronic mechanical stress, friction, pressure, and occlusion.

In the context of sports medicine, the skin of athletes is subjected to repetitive physical нагрузка, leading to the development of specific dermatological conditions such as hyperkeratosis, frictional dermatitis, and microtrauma. However, Paralympic athletes represent a unique population in which these processes are significantly amplified due to additional biomechanical and environmental factors.

Paralympic athletes are frequently exposed to prolonged use of prosthetic devices, orthoses, wheelchairs, and supportive equipment, all of which create persistent mechanical pressure, friction, and occlusive microenvironments. These factors disrupt the normal physiological balance of the skin, leading to alterations in hydration, temperature regulation, and barrier function. Increased humidity and temperature under prosthetic sockets, combined with reduced ventilation, contribute to maceration, microbial overgrowth, and inflammatory reactions.

Furthermore, many Paralympic athletes experience altered sensory perception, impaired microcirculation, and trophic disturbances due to underlying neurological or musculoskeletal conditions. These factors reduce the skin's ability to respond adequately to injury, delay regeneration, and increase susceptibility to chronic inflammation, fissures, and ulceration.

Another important aspect is the role of repetitive mechanical loading and biomechanical redistribution of pressure. In athletes with limb loss or mobility impairment, compensatory mechanisms lead to

abnormal stress distribution across the skin, particularly in areas of contact with prosthetic devices or wheelchair components. Over time, this results in adaptive changes such as epidermal thickening, dermal fibrosis, and disruption of the epidermal barrier.

Recent advances in dermatological research have emphasized the importance of skin barrier function and its quantitative assessment using parameters such as transepidermal water loss (TEWL). Elevated TEWL values indicate compromised barrier integrity and are frequently associated with inflammatory dermatoses and chronic mechanical irritation. In Paralympic athletes, TEWL alterations are particularly evident in areas exposed to prolonged occlusion and friction.

Despite the clinical significance of these changes, current literature remains limited and fragmented, often focusing on isolated conditions rather than providing a comprehensive analysis of adaptive dermatological processes in Paralympic populations. There is a lack of integrated clinical, dermoscopic, and functional studies that systematically evaluate the spectrum of skin changes and their underlying mechanisms.

Therefore, a comprehensive understanding of adaptive skin changes in Paralympic athletes is essential for the development of effective diagnostic, preventive, and therapeutic strategies. Identification of clinical phenotypes and associated risk factors can facilitate a personalized approach to dermatological care, improve athletes' quality of life, and enhance their спортивная performance.

The aim of this study is to evaluate the clinical, dermoscopic, and functional characteristics of adaptive skin changes in Paralympic athletes and to develop phenotype-based corrective approaches for their management.

METHODS

1 Study Design and Population

A cross-sectional study was conducted including 30 Paralympic athletes aged 18–45 years.

2 Methods

The following diagnostic methods were applied:

- Clinical dermatological examination
- Dermoscopy
- TEWL measurement
- High-frequency ultrasound of the skin

3 Statistical Analysis

Data were analyzed using SPSS software. Statistical significance was defined as $p < 0.05$.

RESULTS

The distribution of dermatological conditions was as follows:

- Hyperkeratosis – 72%
- Irritant dermatitis – 65%
- Maceration – 38%
- Trophic changes – 15%

TEWL values were significantly higher in affected areas (16.5 ± 3.2 g/m²/h) compared to unaffected skin ($p < 0.01$).

Ultrasound findings included:

- Epidermal thickening
- Dermal fibrosis
- Reduced echogenicity

DISCUSSION

The findings confirm that adaptive skin changes in Paralympic athletes are driven by multiple interacting factors, including mechanical stress, occlusion, and impaired microcirculation.

Three major clinical phenotypes were identified:

1. Hyperkeratotic phenotype
2. Irritative-inflammatory phenotype
3. Occlusive-maceration phenotype

These phenotypes provide a basis for differential diagnosis and personalized treatment strategies.

The results are consistent with recent studies in sports dermatology, emphasizing the importance of barrier function impairment and chronic mechanical irritation.

Corrective Approaches

Based on the findings, the following corrective strategies are recommended:

- Individual adjustment of prosthetic devices
- Use of barrier-repair creams and emollients
- Regular dermatological monitoring
- Dermoscopy and TEWL assessment

- Modification of training load

CONCLUSION

Adaptive skin changes in Paralympic athletes are common and multifactorial.

Phenotype-based approaches allow for more effective prevention and treatment.

Integration of clinical and instrumental diagnostics improves patient outcomes.

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