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REVIEW
ΑΝΑΣΚΟΠΗΣΗ

The impact of physical activity and outdoor exposure on skin health in football players

The skin is a vital organ in maintaining homeostasis and protecting against environmental insults. However, its role in sports medicine remains underrepresented, particularly in football, where athletes are repeatedly exposed to mechanical friction, ultraviolet radiation, heat, humidity, and synthetic fabrics. These conditions may result in acute and chronic dermatological manifestations, including contact dermatitis, folliculitis, mycoses, and pressure-related lesions. This narrative review summarizes current findings on the impact of external stressors on skin health among football players and discusses clinical implications for prevention and management. Recent technological developments have introduced new methods for real-time skin assessment. Artificial intelligence (AI) applications in dermatology –through machine learning algorithms, wearable sensors, sweat analysis systems, and mobile health platforms– have demonstrated increasing accuracy in the detection and monitoring of dermatological conditions. Devices such as electronic skin patches and thermographic tools enable the continuous collection of skin-related data, allowing for early identification of pathological changes and potentially guiding intervention. This review evaluates the integration of AI-enabled monitoring systems within football-specific medical protocols. Evidence from recent studies supports their utility in screening and follow-up, although most tools require further validation in sports-specific contexts. The application of AI in dermatological monitoring may enhance clinical decision-making, especially in outdoor sports where environmental exposure is high. Further research should investigate the reliability, reproducibility, and clinical effectiveness of these technologies in diverse athletic populations. Standardization of protocols and interdisciplinary collaboration between sports physicians, dermatologists, and engineers are essential for the development of practical tools for routine use.

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ΑΡΧΕΙΑ ΕΛΛΗΝΙΚΗΣ ΙΑΤΡΙΚΗΣ 2026, 43(4):467–473

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Η επίδραση της σωματικής δραστηριότητας και της εξωτερικής έκθεσης στην υγεία του δέρματος των ποδοσφαιριστών

Περίληψη στο τέλος του άρθρου

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1. INTRODUCTION

The skin, the body's largest organ, plays a critical role in thermoregulation, immune defense, fluid balance, and sensory perception.[1] In the context of elite sports, particularly football, the skin is exposed to a convergence of mechanical, environmental, and metabolic stressors that can lead to both acute and chronic dermatological conditions.[2] Football players routinely face prolonged sun exposure, repeated sweating, high contact with equipment and uniforms, and variable climatic conditions, all of which challenge skin barrier integrity and homeostasis.[3,4] Physical activity itself can alter skin characteristics through increased circulation, elevated sweat production, mechanical friction, and temperature fluctuations.[5] While sweat is essential for thermoregulation, its accumulation, especially under occlusive conditions, can promote microbial growth, irritation, and salt imbalance.[6,7] Furthermore, exposure to ultraviolet (UV) radiation and airborne pollutants during outdoor activities contributes to oxidative stress, inflammation, and accelerated skin aging.[8,9] Despite these risks, skin health in athletes remains relatively underrepresented in sports science literature. However, emerging technologies in digital health and wearable monitoring are reshaping this landscape. Artificial intelligence (AI), combined with skin-interfaced sensors and mobile health applications, now

allows for continuous, real-time tracking of skin parameters such as hydration, sweat rate, pH, and temperature.[10,11] In parallel, AI-based tools have demonstrated high accuracy in dermatological diagnostics, particularly in detecting skin cancer and other lesions in both clinical and remote settings.[12–14]

This narrative review aims to bridge the gap between sports dermatology, exercise physiology, and artificial intelligence by offering an integrated perspective on how physical and environmental stressors affect the skin of football players. Specifically, it explores the potential of AI-enhanced tools –such as wearable sensors, mobile health platforms, and machine learning algorithms– for real-time monitoring and personalized management of skin health in football contexts. The central objectives of this review are threefold: (a) To synthesize current knowledge on the physiological and environmental impacts of football on skin health, (b) to evaluate the emerging role of AI technologies in dermatological assessment and intervention, and (c) to identify potential applications and future directions for integrating skin monitoring into athletic care. Key research questions include: How do football-specific stressors contribute to skin dysfunction? What are the current capabilities and limitations of AI-based dermatological tools in sports settings? And how can such technologies be effectively implemented in daily football practice to support performance, recovery, and long-term skin health?

2. EXERCISE AND SKIN HEALTH

Physical activity, while essential for systemic health and athletic performance, imposes complex demands on the skin.[15] During intense exercise, the skin undergoes multiple physiological changes to support thermoregulation, including increased blood flow, heightened sweat gland activity, and changes in skin surface temperature.[1,16] In football, these effects are magnified by prolonged training durations, frequent outdoor exposure, and the use of tight-fitting or synthetic gear that impairs sweat evaporation and increases mechanical friction. Sweating is a critical thermoregulatory response but also a potential dermatological stressor. When sweat accumulates on the skin surface –especially under occlusive equipment such as shin guards, socks, and compression garments– it can alter skin pH, increase susceptibility to microbial overgrowth, and contribute to conditions such as intertrigo, acne mechanica, and irritant contact dermatitis.[6,7] Moreover, dehydration and rehydration cycles significantly impact skin elasticity, surface hydration, and roughness, with implications for skin barrier integrity and wound susceptibility in athletes.[3] Mechanical loading from repetitive movements, tackles, and gear also affects the skin. Friction and pressure points may lead to callus formation, abrasions, and blisters, which, if left unmanaged, can evolve into secondary infections or chronic wounds.[17,18] Physical activity has been shown to influence scar remodeling and tissue regeneration via mechanotransduction pathways, suggesting that exercise can both aggravate and facilitate skin tissue recovery, depending on the context.[19]

Importantly, physical activity may also have beneficial effects on skin health. Resistance training has been shown to reduce circulating inflammatory factors and stimulate extracellular matrix remodeling in aging skin, indicating a regenerative potential.[20] These findings highlight the bidirectional nature of exercise on the skin, posing both risks and benefits. Despite the known physiological and mechanical impacts of exercise on skin, dermatological monitoring remains uncommon in sports science, where emphasis is typically placed on cardiovascular and musculoskeletal systems. As awareness grows regarding the skin's role in athletic performance, comfort, and injury prevention, the integration of dermatological assessment into athlete health protocols becomes increasingly necessary. A clinical review has reported that conditions such as bacterial folliculitis, tinea corporis, and contact dermatitis are prevalent in athletes and should be promptly identified and managed with individualized return-to-play strategies.[21]

3. ENVIRONMENTAL EXPOSURES IN OUTDOOR FOOTBALL

Outdoor football inherently exposes athletes to a range of environmental stressors that interact with physical activity to influence skin health. Among the most significant of these is ultraviolet (UV) radiation.[22] Prolonged exposure during training and matches can lead to photodamage, hyperpigmentation, erythema, and long-term effects such as photoaging and increased skin cancer risk.[23] This concern is particularly relevant given the documented rise in melanoma and other skin cancers among outdoor sports participants.[24] AI-supported diagnostic tools are now improving early detection, offering more timely interventions for at-risk athletes. Environmental heat and humidity further compound these risks by intensifying sweat production and elevating thermal strain. Athletes exposed to hot conditions experience not only elevated core temperatures but also increased skin surface temperatures, which can disrupt sweat dynamics and promote conditions such as miliaria and superficial fungal infections.[3,16] Maintaining hydration under these conditions is critical, as dehydration has been shown to reduce skin elasticity and impair the barrier

function, thereby increasing vulnerability to mechanical damage and microbial invasion.[3] Airborne pollutants also have dermatological significance. Athletes training in urban environments may encounter fine particulate matter and chemical irritants that can penetrate the skin barrier and provoke oxidative stress and inflammation.[25,26] Although not football-specific, the broader literature indicates that such exposures can disturb the skin microbiome and accelerate aging.[9] Furthermore, protective gear commonly worn during football, such as tight-fitting socks, shin guards, and synthetic jerseys, can act as localized stressors.[27] These materials often trap heat and moisture, creating microenvironments conducive to bacterial or fungal growth, and increasing the risk of friction-related skin damage.[28] Similar skin damage patterns were observed among healthcare workers during the COVID-19 pandemic due to prolonged use of personal protective equipment.[4]

These converging environmental and mechanical stressors underscore the importance of real-time context-specific skin health monitoring. AI-enhanced wearable sensors and mobile diagnostic systems are emerging as valuable tools for quantifying UV exposure, sweat composition, and skin temperature fluctuations during field play.[10,11] By enabling dynamic and personalized data collection, these technologies can guide targeted interventions for skin protection, hydration, and recovery. Supporting this need, a recent cross-sectional study found that more than 60% of sports students reported experiencing skin complaints related to physical activity, including frictional irritation, sweat-induced dermatitis, and infections.[29] These findings reflect the dermatological burden associated with intense training loads, and further highlight the need for proactive sport-specific prevention strategies in football environments.

4. SWEAT AS A DIAGNOSTIC MEDIUM

Sweat plays a dual role in sports performance; it is essential for thermoregulation,[30] yet it also presents diagnostic opportunities for assessing the physiological status.[31] In football players, where high-intensity activity and outdoor exposure are constant, sweat can offer valuable insights into hydration, electrolyte balance, thermoregulatory efficiency, and even psychological stress.[32] Recent studies highlight sweat's utility as a biofluid rich in biomarkers such as sodium, potassium, lactate, glucose, and cortisol, which can be measured to monitor physiological strain and metabolic health.[6] Sweat sensors have evolved into compact, skin-adhered microfluidic systems capable of real-time measurement of these analytes. For instance, Ray et al[10] demonstrated the effectiveness of skin-interfaced "sweat stickers" in non-invasively diagnosing cystic fibrosis, paving the way for similar applications in sports contexts. In addition to biochemistry, sweat rate and distribution offer clues to hydration status and thermoregulatory efficiency. Eda et al[3] reported significant changes in skin characteristics with dehydration and rehydration cycles, reinforcing the role of sweat dynamics in skin health and performance. The integration of thermographic and wearable technologies can thus help prevent heat stress and guide individualized rehydration strategies.

Individual variability in sweat rate and response has also been linked to factors such as tattoo characteristics and skin condition.[33] These nuances underscore the value of AI-assisted interpretation, where machine learning algorithms can analyze sweat data patterns to generate athlete-specific feedback. Further, AI-powered sweat monitoring systems have the potential to address equity in health diagnostics. Clark and Ray[11] emphasized that wearable sweat technologies, if made widely accessible, could support equitable health monitoring in underserved populations, including athletes in lower-resource environments. From a regenerative medicine perspective, sweat glands are not just passive ducts; they actively interact with the skin's vascular and stem cell niches. Yuan et al[7] described a reciprocal relationship between vascular structures and sweat glands that facilitates tissue regeneration, an area with implications for both injury recovery and long-term skin integrity in athletes. Collectively, these insights position sweat as a highly informative, non-invasive diagnostic medium that can be leveraged through wearable sensors and AI systems to enhance performance monitoring, prevent heat-related illness, and preserve skin health in football players.

5. ARTIFICIAL INTELLIGENCE-BASED TOOLS IN SKIN HEALTH MONITORING

Artificial intelligence is rapidly transforming the landscape of dermatological care and has shown significant promise in both clinical and sports contexts. By leveraging machine learning algorithms, computer vision, and large-scale datasets, AI can enhance skin health monitoring through improved diagnostic accuracy, real-time assessment, and personalized recommendations.[34] In clinical dermatology, AI systems have demonstrated diagnostic performance comparable to expert dermatologists in identifying a wide range of skin conditions, particularly skin cancers. Brancaccio et al[12] emphasized that while AI models show high sensitivity for detecting melanoma, their integration into real-world workflows requires rigorous validation. Similarly, Escalé-Besa et al[14] and Wei et al[35]

reported improvements in lesion recognition and triage accuracy in primary care settings using AI-based image analysis tools. The expansion of AI into point-of-care and mobile health applications is particularly relevant for football players and other outdoor athletes. AI-powered tools can now operate via smartphones or portable devices, enabling remote skin assessments and early detection of abnormal changes.[13,36] In one feasibility study, Gregoor et al[37] demonstrated that AI tools used at home could support skin cancer diagnostics, suggesting their potential for field-based athletic environments. These innovations have been further enhanced by wearable technologies that integrate AI-driven analytics with continuous data collection. For example, e-skin devices and microfluidic sensors can monitor sweat composition, hydration status, and skin temperature in real-time.[6,10] When linked to AI platforms, these devices provide actionable insights such as early warnings for dehydration, heat stress, or skin irritation, key concerns in football. Moreover, AI-based systems are increasingly being designed with equity in mind. As noted by Lee et al,[38] the dermatological AI field has historically been biased toward lighter skin tones, raising concerns about diagnostic accuracy in diverse populations. Current efforts aim to diversify training datasets and improve model generalizability, which is critical for use in sports. AI's integration into teledermatology and clinical workflows also extends to the decision-making process for non-specialists. Tools developed for primary care physicians and nurse practitioners have been shown to increase diagnostic accuracy and reduce referral delays.[13] These capabilities are applicable in team sports settings, where immediate access to dermatology specialists may be limited.

In summary, AI-driven technologies offer a novel, scalable, and personalized approach to skin health monitoring in football players. These tools can assist in early detection of dermatological issues, guide preventive strategies, and enhance athlete care in both clinical and field environments. Figure 1 illustrates the integration of AI technologies into skin health monitoring for football players. It highlights clinical diagnostic tools, mobile health applications, and wearable sensors enhanced by AI analytics. Core components include: (a) AI-driven skin lesion detection systems used in dermatology and primary care; (b) mobile and teledermatology platforms for remote assessment; (c) wearable e-skin and sweat sensors for real-time monitoring of hydration, temperature, and irritation risk; and (d) data equity initiatives aimed at improving diagnostic accuracy across diverse skin types. Together, these tools enable early detection, prevention, and personalized care in both clinical and on-field athletic environments.

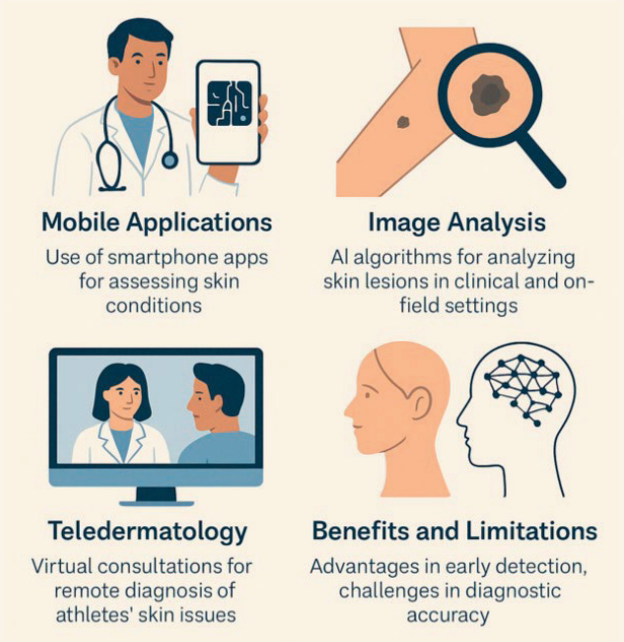

Figure 1. The role of artificial intelligence in monitoring and managing skin health in athletes.

6. INTEGRATION IN FOOTBALL PERFORMANCE AND RECOVERY

In elite football, maintaining skin integrity is becoming a recognized component of comprehensive athlete health and performance management.[39] The cumulative burden of intense physical exertion, outdoor environmental stress, and prolonged use of occlusive gear can compromise skin function, contributing to discomfort, inflammation, and secondary complications that affect training continuity and injury risk. Emerging AI-driven technologies offer a novel opportunity to incorporate skin health monitoring into routine performance management systems. Wearable biosensors, including microfluidic "sweat stickers" and e-skin platforms, now allow for real-time assessment of hydration levels, electrolyte concentrations, sweat composition, and skin temperature.[6,10] When these data streams are integrated with AI algorithms, they can detect early warning signs of thermal strain, dehydration, and barrier disruption, conditions that might otherwise go unnoticed until they impair recovery or performance.[3,33]

In applied football contexts, such technologies can be embedded into daily routines. Personalized sweat profiles, for instance, could inform individualized hydration strategies or guide adjustments in clothing and equipment to reduce friction-induced skin damage. AI-informed dashboards may alert sports medicine teams to abnormal dermatological patterns or suggest rest and cooling inter-

ventions based on weather conditions, skin responses, and physical load.[1,11] AI's utility also extends into rehabilitation. Managing scar tissue, skin sensitivity, or thermoregulatory dysfunction during injury recovery demands the precise tracking of local inflammation and tissue remodeling. AI-enhanced imaging or wearable thermography could assist clinicians in monitoring healing trajectories and adjusting therapy accordingly.[19] Importantly, these tools are not conceptual; they are increasingly being used in real-world sports environments. For example, professional football teams already employ wearable systems to monitor metrics like muscle oxygen saturation and hydration status, enabling real-time adjustments to optimize performance and reduce injury risk.[40] The same platforms could be adapted to track dermatological parameters such as sweat pH, transepidermal water loss, and skin temperature. As mobile health and teledermatology platforms mature, they offer scalable solutions for integrating dermatological care into athletic health systems, even in settings with limited access to specialist support.[13,37] However, their deployment must be guided by considerations of data privacy, device usability, and fairness. AI models trained primarily on lighter skin tones may perform poorly across diverse populations, underscoring the need for equity-centered design in athletic monitoring tools.[38] By incorporating AI-enhanced skin health tracking into football's existing performance infrastructure, sports organizations can reduce preventable dermatological problems, support personalized recovery strategies, and improve athlete well-being across competitive levels.

7. FUTURE DIRECTIONS AND CHALLENGES

The integration of AI and wearable technologies into skin health monitoring in football players represents a promising frontier in sports science. However, several challenges and opportunities remain before such tools can be widely and effectively implemented in practice. One of the most critical needs is the validation and standardization of AI algorithms across diverse populations and use contexts. Much of the existing dermatological AI has been developed and tested using datasets predominantly composed of lighter skin tones, raising significant concerns regarding diagnostic accuracy in athletes with darker skin.[38] Ensuring algorithmic equity is not only an ethical imperative but also essential for minimizing misdiagnoses and maximizing the utility of AI in global football contexts. Another important issue is data privacy and ethical governance. As AI-based monitoring becomes more personalized and continuous, sensitive biometric and visual data from athletes must be securely managed. Transparent consent processes and robust data protection protocols are essential, especially when integrating wearable sensor data into centralized athlete monitoring platforms. The usability and practicality of skin-monitoring devices in high-movement, high-contact sports like football also demand attention. While systems such as sweat sensors and e-skin patches are advancing rapidly, their durability, adhesion, and comfort during match play need to be optimized.[6,10] Additionally, AI platforms must be designed to provide interpretable feedback, ensuring that medical teams and coaches can make informed decisions without requiring deep technical expertise. From a clinical and sports science perspective, research gaps persist. More field-based studies are needed to evaluate the long-term effects of outdoor physical activity on skin aging, barrier function, and microbiome integrity in athletes.[3,9] There is also a need to explore synergies between dermatological AI and other health domains, such as hydration monitoring, injury prevention, and thermoregulation. Opportunities also lie in the scalability of AI for resource-limited settings. Mobile health applications and teledermatology platforms have already demonstrated feasibility in public health and home-based contexts.[13,37] Extending these tools to youth and amateur football programs could democratize access to dermatological care and preventive monitoring. Lastly, interdisciplinary collaboration between sports scientists, dermatologists, bioengineers, and AI developers could be crucial. Effective translation from laboratory settings to the football field requires systems that are not only accurate and safe, but also aligned with the daily realities and performance goals of athletes.

8. CONCLUSIONS

This narrative review examined the interplay between physical activity, environmental exposure, and skin health in football players, while highlighting the emerging potential of AI for real-time dermatological monitoring. Drawing on interdisciplinary evidence, we proposed that AI-driven tools —such as wearable sweat sensors, e-skin technologies, and mobile health applications— may offer personalized solutions for protecting skin integrity in athletic environments. The current work offers a broad, integrative perspective on a relatively overlooked aspect of sports medicine. However, it presents several limitations. First, the review was not conducted using a systematic search strategy and thus, may have omitted relevant studies. Second, the evidence included varies in quality and scope, as no formal risk-of-bias assessment or grading of evidence was applied. Third,

while the discussion of AI applications is conceptually rich, it remains partly speculative due to the limited number of field-based implementations in football contexts.

Despite these constraints, the findings carry important practical implications. AI-enhanced skin monitoring tools could be embedded into performance and medical workflows to detect early signs of irritation, dehydration, or heat stress. Such technologies may improve individualized recovery, inform equipment and hydration strategies, and reduce dermatological complications across playing levels. Looking ahead, recognizing the skin as a vital interface between performance, health, and technology opens new opportunities for innovation, and challenges conventional boundaries in football science.

ΠΕΡΙΛΗΨΗ

Η επίδραση της σωματικής δραστηριότητας και της εξωτερικής έκθεσης στην υγεία του δέρματος των ποδοσφαιριστών

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Το δέρμα είναι ένα σημαντικό όργανο για τη διατήρηση της ομοιόστασης και την προστασία του οργανισμού από περιβαλλοντικές προσβολές. Στο ποδόσφαιρο, όπου επικρατούν μηχανική τριβή, υπεριώδης ακτινοβολία και υψηλή υγρασία, οι αθλητές αντιμετωπίζουν δερματολογικά προβλήματα, όπως δερματίτιδες και τραύματα λόγω τριβής. Η παρούσα μελέτη εξετάζει την επίδραση αυτών των παραγόντων και προτείνει προληπτικά μέτρα. Πρόσφατες τεχνολογικές καινοτομίες, όπως η τεχνητή νοημοσύνη (ΤΝ) και αισθητήρες, επιτρέπουν την παρακολούθηση σε πραγματικό χρόνο της δερματικής υγείας. Ειδικά εργαλεία (π.χ. ηλεκτρονικά επιθέματα δέρματος) αναγνωρίζουν νωρίς παθολογικές αλλαγές, βελτιώνοντας την πρόληψη και τη θεραπευτική αγωγή. Παρ' όλο που οι εν λόγω τεχνολογίες έχουν αποδειχθεί χρήσιμες σε κλινικά πρωτόκολλα, απαιτούν περαιτέρω επικύρωση για αθλητικές πληθυσμιακές ομάδες. Η εφαρμογή τους στο ποδόσφαιρο μπορεί να βελτιώσει τη λήψη αποφάσεων, ιδιαίτερα σε συνθήκες έντονης περιβαλλοντικής έκθεσης. Συμπερασματικά, είναι απαραίτητη η περαιτέρω έρευνα για την αξιολόγηση της αξιοπιστίας και της κλινικής αποτελεσματικότητας αυτών των εργαλείων, καθώς και η τυποποίηση των πρωτοκόλλων χρήσης τους. Η διαθεματική συνεργασία μεταξύ ειδικών είναι καθοριστική για την ανάπτυξη ολοκληρωμένων λύσεων.

Λέξεις ευρετηρίου: Αθλητιατρική, Δερματολογία, Ποδόσφαιρο, Τεχνητή νοημοσύνη, Φορητές ηλεκτρονικές συσκευές

References

1. TRAVERS G, KIPPELEN P, TRANGMAR SJ, GONZÁLEZ-ALONSO J. Physiological function during exercise and environmental stress in humans – an integrative view of body systems and homeostasis. *Cells* 2022, 11:383
2. ADAMS BB. Dermatologic disorders of the athlete. *Sports Med* 2002, 32:309–321
3. EDA N, NAKAMURA N, INAI Y, SUN Z, SONE R, WATANABE K ET AL. Changes in the skin characteristics associated with dehydration and rehydration. *Eur J Sport Sci* 2023, 23:552–560
4. JOSE S, CYRIAC MC, DHANDAPANI M. Health problems and skin damage caused by personal protective equipment: Experience of frontline nurses caring for critical COVID-19 patients in intensive care units. *Indian J Crit Care Med* 2021, 25:134–139
5. GLEESON M. Temperature regulation during exercise. *Int J Sports Med* 1998, 19(Suppl 2):S96–S99
6. TABASUM H, GILL N, MISHRA R, LONE S. Wearable microfluidic-based e-skin sweat sensors. *RSC Adv* 2022, 12:8691–8707
7. YUAN X, DUAN X, ENHEJIRIGALA, LI Z, YAO B, SONG W ET AL. Reciprocal interaction between vascular niche and sweat gland promotes sweat gland regeneration. *Bioact Mater* 2022, 21:340–357
8. CÂNDIDO TM, ARIEDE MB, LIMA FV, GUEDES LS, VELASCO MVR, BABY AR ET AL. Dietary supplements and the skin: Focus on photoprotection and antioxidant activity – a review. *Nutrients* 2022, 14:1248
9. KHMALADZE I, LEONARDI M, FABRE S, MESSARAA C, MAVON A. The skin interactome: A holistic "genome-microbiome-exposome" approach to understand and modulate skin health and aging. *Clin Cosmet Investig Dermatol* 2020, 13:1021–1040
10. RAY TR, IVANOVIC M, CURTIS PM, FRANKLIN D, GUVENTURK K, JEANG

WJ ET AL. Soft, skin-interfaced sweat stickers for cystic fibrosis diagnosis and management. *Sci Transl Med* 2021, 13:eabd8109
11. CLARK KM, RAY TR. Recent advances in skin-interfaced wearable sweat sensors: Opportunities for equitable personalized medicine and global health diagnostics. *ACS Sens* 2023, 8:3606–3622
12. BRANCACCIO G, BALATO A, MALVEHY J, PUIG S, ARGENZIANO G, KITTLER H. Artificial intelligence in skin cancer diagnosis: A reality check. *J Invest Dermatol* 2024, 144:492–499
13. JAIN A, WAY D, GUPTA V, GAO Y, MARINHO GO, HARTFORD J ET AL. Development and assessment of an artificial intelligence-based tool for skin condition diagnosis by primary care physicians and nurse practitioners in teledermatology practices. *JAMA Netw Open* 2021, 4:e217249
14. ESCALÉ-BESA A, YÉLAMOS O, VIDAL-ALABALL J, FUSTER-CASANOVAS A, CATALINA QM, BÖRVE A ET AL. Exploring the potential of artificial intelligence in improving skin lesion diagnosis in primary care. *Sci Rep* 2023, 13:4293
15. FORMENTI D, LUDWIG N, GARGANO M, GONDOLA M, DELLERMA N, CAUMO A ET AL. Thermal imaging of exercise-associated skin temperature changes in trained and untrained female subjects. *Ann Biomed Eng* 2013, 41:863–871
16. CHOU TH, COYLE EF. Cardiovascular responses to hot skin at rest and during exercise. *Temperature (Austin)* 2022, 10:326–357
17. BRENNAN FH Jr. Managing blisters in competitive athletes. *Curr Sports Med Rep* 2002, 1:319–322
18. BERGFELD WF, TAYLOR JS. Trauma, sports, and the skin. *Am J Ind Med* 1985, 8:403–413
19. DEFLORIN C, HOHENAUER E, STOOP R, VAN DAELE U, CLIJSEN R, TAEYMANS J. Physical management of scar tissue: A systematic review and meta-analysis. *J Altern Complement Med* 2020, 26:854–865
20. NISHIKORI S, YASUDA J, MURATA K, TAKEGAKI J, HARADA Y, SHIRAI Y ET AL. Resistance training rejuvenates aging skin by reducing circulating inflammatory factors and enhancing dermal extracellular matrices. *Sci Rep* 2023, 13:10214
21. PUJALTE GGA, COSTA LMC, CLAPP AD, PRESUTTI RJ, SLUZEVICH JC. More than skin deep: Dermatologic conditions in athletes. *Sports Health* 2023, 15:74-85
22. SCHNEIDER S, PARSONS ZA, LEER S. Beyond the scoreboard: Coaches' UV-related skin cancer knowledge in outdoor sports. *J Eur Acad Dermatol Venereol* 2025, 39:1297–1305
23. ANDREWS L, SHOPE C, SNYDER A, VALDEBRAN M. Commentary: Sport-specific factors impacting solar ultraviolet exposure in individuals who perform outdoor sport activities. *J Dermatol Skin Sci* 2022, 4:7–9
24. MILLER IJ, STAPELBERG M, ROSIC N, HUDSON J, COXON P, FURNESS J ET AL. Implementation of artificial intelligence for the detection of cutaneous melanoma within a primary care setting: Prevalence and types of skin cancer in outdoor enthusiasts. *Peer J* 2023, 11:e15737
25. JAFFRI JM. Reactive oxygen species and antioxidant system in selected skin disorders. *Malays J Med Sci* 2023, 30:7–20
26. ANGELOVA-FISCHER I, DAPIC I, HOEK AK, JAKASA I, FISCHER TW, ZILLIKENS D ET AL. Skin barrier integrity and natural moisturising factor levels after cumulative dermal exposure to alkaline agents in atopic dermatitis. *Acta Derm Venereol* 2014, 94:640–644
27. MANIÈRE I, AUBERT A, DUBOIS C, SOLAL C, LEPOITTEVIN JP, ROUSSELLE C. Sensitization properties of acetophenone azine, a new skin sensitizer identified in textile. *Contact Dermatitis* 2023, 88:35–42
28. SREEPADMANABH M, GANESH M, SANJENBAM P, KURZTHALER C, AGASHE D, BHATTACHARJEE T. Cell shape affects bacterial colony growth under physical confinement. *Nat Commun* 2024, 15:9561
29. DREWITZ KP, HASENPUSCH C, KREUZPOINTNER F, SCHWIRTZ A, KLENK A, APFELBACHER CJ. Cross-sectional study on exercise-related skin complaints among sports students at two German universities. *Sci Rep* 2024, 14:11829
30. NASRIN S, MANDAL S, ISLAM MM, PETROVA A, AGNEW RJ, BOORADY LM. Factors affecting the sweat-drying performance of active sportswear – a review. *Textiles* 2023, 3:319–338
31. WANG X, ZHANG H, LI J, ZOU G. Monitoring of sweat pH and dual-mode anti-counterfeiting from metal-organic framework-based multifunctional gel. *Chin J Chem* 2024, 42:491–498
32. PLAKIAS S, TSATALAS T, MINA MA, KOKKOTIS C, FLOURIS AD, GIAKAS G. The impact of heat exposure on the health and performance of soccer players: A narrative review and bibliometric analysis. *Sports (Basel)* 2024, 12:249
33. KEYES DM, BROWN SD, KING MA, ENGEL MD, CICIORA-GOLD M, DE CHAVEZ PJD ET AL. Multiple regression analyses to determine the effect of sweating rate and tattoo characteristics on sweat outcome measures during exercise. *Eur J Appl Physiol* 2022, 122:2163–2174
34. DU AX, EMAM S, GNIADECKI R. Review of machine learning in predicting dermatological outcomes. *Front Med (Lausanne)* 2020, 7:266
35. WEI ML, TADA M, SO A, TORRES R. Artificial intelligence and skin cancer. *Front Med (Lausanne)* 2024, 11:1331895
36. DULMAGE B, TEGTMEYER K, ZHANG MZ, COLAVINCENZO M, XU S. A point-of-care, real-time artificial intelligence system to support clinician diagnosis of a wide range of skin diseases. *J Invest Dermatol* 2021, 141:1230–1235
37. GREGOOR AMS, SANGERS TE, EEKHOF JA, HOWE S, REVELMAN J, LITJENS RJ ET AL. Artificial intelligence in mobile health for skin cancer diagnostics at home (AIM HIGH): A pilot feasibility study. *EClinicalMedicine* 2023, 60:102019
38. LEE MS, GUO LN, NAMBUDIRI VE. Towards gender equity in artificial intelligence and machine learning applications in dermatology. *J Am Med Inform Assoc* 2022, 29:400–403
39. ZINDER SM, BASLER RS, FOLEY J, SCARLATA C, VASILY DB. National athletic trainers' association position statement: Skin diseases. *J Athl Train* 2010, 45:411–428
40. LEHIGH UNIVERSITY. Wearable tech a game-changer for athletes' performance. Lehigh University, Bethlehem, PA, 2024. Available at: https://news.lehigh.edu/wearable-tech-a-game-changer-for-athletes-performance

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