Influence of Sleep and Western Diet in Psoriasis

Subjects: Dermatology

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The World Health Organization (WHO) reports psoriasis (PsO) as one of the five diseases that drastically influence patients' quality of life. PsO is a systemic, chronic inflammatory skin disease related to epidermal keratinocyte hyperplasia and epidermal immune cell over-activation via the interleukin (IL)-23/IL-17 axis. It is one of the most common chronic inflammatory skin diseases, with a prevalence of 1–2% worldwide, and almost 6–11% of patients with PsO may have inflammatory arthropathy (psoriatic arthritis).

psoriasis sleep sleep disorders western diet diet

1. Sleep and Psoriasis

psoriasis (PsO) seems to affect sleep quality, and this clinical finding is also confirmed by extensive epidemiological studies [1][2][3][4][5][6][7][8][9][10][11][12][13][14][15][16][17][18][19][20][21][22][23][24][25]. Recent studies displayed that obstructive sleep apnea (OSA) patients doubled the risk of PsO and psoriatic arthritis (PsA) compared with heathy ones [11][12][13][16]. To further confirm this trend, PsO patients were found to be at higher risk of OSA than the general population using the apnea–hypopnea index (AHI) > 5 [1]. Researchers also observed an increase in the prevalence of resting leg syndrome (RLS) in PsO, with 15.1% and 18% in PsO versus 5% and 10% in the general populations in Europe and North America, respectively. Importantly, Chiu et al. [15] indicated that the concomitant presence of OSA and PsO exposed patients to a higher risk of Major Adverse Cardiovascular Events (MACE), especially ischemic heart attack and stroke.

Sleep disorders seem to be linked to PsO in a vicious circle in which one disease increases the risk of the other, with inflammation as a pathogenic basis bi-directionally linking sleep disorders and PsO [25][26][27][28][29][30][31][32][33][34][35][36][37][38][39]. In the PsO-to-sleep disorders directionality, there are various potential mechanisms through which PsO can act on sleep. These mechanisms operate through both direct and indirect effects. The direct effects are due to cutaneous symptoms present in PsO, such as pruritus, pain, burning sensations or, in the case of PsA, inability to move [6][17][18][19][20][21][40]. Pruritus in PsO often exhibits and/or increases during the evening, since it is regulated by circadian factors—for instance, lower cortisol levels and decreased epidermal barrier function—that lower the threshold for pruritus [8][18][19][20][21][22][23][24]. In addition, the skin plays an important role in sleep initiation, as it acts on thermoregulation and the control of the body core temperature, which normally decreases in the late evening. In contrast, these mechanisms result to be altered in PsO, where the skin diminishes the ability to dissipate heat and exhibits altered thermoregulation [30]. Instead, the indirect effects through which PsO contributes

to the risk of sleep disorders may be attributable to psoriasis comorbidities that share with psoriasis a common underlying inflammatory basis [26][27][28][31]. In particular, diabetes and hypertension [35][36][38][39] were shown to be associated with insomnia, while cardiovascular disease, diabetes, obesity and psychiatric disorders were associated with OSA [37]. At the same time, systemic inflammation triggered by several pathological conditions such as OSA or even insomnia may trigger PsO flares and vice versa, thus a multidisciplinary evaluation in patients with chronic inflammation should always be considered.

On the other hand, regarding psoriasis-related sleep disorders, recent studies suggested that a possible pathogenetic mechanism could be the overproduction of oxygen radicals due to the massive pro-inflammatory cytokines spill-over from the skin and other inflamed tissues [40]. Their inhibition with biologics seems to restore the oneiric dimension, by attenuating circadian rhythm dysregulation; from this perspective, also by properly treating sleep disorders, it can be hypothesized that the possibility to develop PsO can be decreased, especially in patients with positive family history.

1.1. Pro-Inflammatory Cytokines Shared between Sleep Disorders and Psoriasis

Common inflammatory networks are involved in the pathomechanisms underlying both sleep disorders and psoriasis [34]. In particular, pro-inflammatory cytokines such as TNF-α and IL-6 play a role in the pathogenesis of psoriasis and are implicated in sleep regulation [41]. These cytokines can be secreted by peripheral immune cells and by astrocytes and microglia in the central nervous system in response to poor sleep quantity and quality during the previous night, and produce the effect of daytime sleepiness, commonly seen in OSA. On the other hand, in chronic insomnia, there is a shift in the timing of TNF and IL-6 secretion, eliciting a modification of the hypothalamus–pituitary–adrenal axis and the hypersecretion of cortisol, that plays a role in increased wakefulness. Therefore, it is well defined that sleep deprivation can affect the immunological integrity and nocturnal secretion of cytokines, increasing the risk of PsO. Hirotsu et al. [7] examined the influence of sleep loss in an animal model of PsO by measuring cytokine and stress-related hormone levels. Male adult Balb/C mice with or without PsO were subjected to 48 h of selective paradoxical sleep deprivation. Sleep deprivation enhanced the activities of serine proteases—kallikrein-5 and kallikrein-7—which led to desquamation in the skin of psoriatic groups. In addition, mice with PsO had significant increases in specific pro-inflammatory cytokines (IL-1β, IL-6 and IL-12) and decreases in the anti-inflammatory cytokine (IL-10) after sleep deprivation, which were normalized after 48 h of sleep rebound. Another cytokine in common between sleep disorders and PsO is vascular endothelial growth factor (VEGF). Its levels are elevated in patients with severe OSA and stimulate angiogenesis and inflammation in psoriatic skin [42][43]. Moreover, studies observed that both PsO and sleep deprivation are associated with reduced levels of adiponectin, an anti-inflammatory adipokine, or increased ghrelin and decreased leptin levels, an imbalance leading to a raised feeling of hunger and appetite that increases caloric intake and subsequently the risk of overweight or obesity conditions [44]. Obesity remains one of main comorbidities associated with both PsO and sleep disorders, suggesting a potential common pathomechanism.

1.2. Effects of Conventional and Biological Psoriasis Therapy on Sleep Disorders

Interestingly, conventional therapies may also influence sleep quality. In fact, cyclosporin improves sleep with a fast efficacy in skin lesions [45], and methotrexate is slower but also acts on joint pain in PsA patients [46]; conversely, acitretin may de-regulate the circadian rhythm, causing insomnia [47].

To date, the impact of biological treatment (or immunotherapy) on sleep outcomes in PsO patients is poorly considered in clinical research [33]. Nevertheless, Thaçi and colleagues [9] examined PsO patients with PASI greater than 10 that deserved biological therapy (etanercept) and observed them for 24 weeks, also checking sleep parameters. They concluded that by antagonizing TNF-alpha, sleep quality drastically improved in these patients, and the current results may sustain the hypothesis that systemic inflammation may trigger/elicit or even maintain sleep disorders.

Vgontzas et al. [14] further confirmed a role of TNF-alpha in the pathogenesis of OSA by treating these patients with etanercept, obtaining greater results than with continuous positive airway pressure. Interestingly, Strober et al. tested another TNF-alpha inhibitor, namely, adamilumab, for 16 weeks, finding that beside DLQI and PASI, it also improved sleep quality in PsO patients. Remarkably, no animal models are available, and the cause–effect relation between TNF-alpha inhibition and sleep remains to be further demonstrated, since DLQI and PASI improvements may condition sleep quality. Beside direct and indirect PsO-related influence on sleep quality, these data suggest the pathogenic role of inflammatory molecules in the link between PsO and sleep disorders [48][49][50][51][52][53][54]. Interestingly, no data are present in the literature about sleep quality and inhibitors of the IL-17/IL-23 pathway. Sleep quality in PsA patients is associated with the extinguishment of joint pain, CRP and disease duration, as well as, in PsO patients, cutaneous severity, duration and patient age [46]. Thus, anti-psoriatic drug efficacy is the main sleep modulator.

2. Western Diet and Psoriasis

Recently, the western diet has started to be regarded as a prominent modulator of PsO severity and even as a risk factor for its development [55][56][57]. This dietary pattern, which has spread with the industrial revolution and the Modern Age, is characterized by being rich in saturated fats, trans fatty acids (FAs) and n-6 FAs, refined carbohydrates and salt, and reduced intake of n-3 FAs and monounsaturated fatty acids (MUFAs), as well as antioxidants, due to the high intake of red meat, dairies and sugars, and low intake of vegetables and fruits [58][59]. Solid evidence links this diet to the development of metabolic diseases including obesity and type 2 diabetes, as well as atherosclerosis, neurodegeneration and cancer, through mechanisms involving the instigation of chronic inflammation, oxidative stress and alterations in gut microbiota (dysbiosis) [60]. Patients with PsO presented unbalanced dietary habits resembling the western diet, as testified by their dysmetabolism clinically manifesting in obesity, metabolic syndrome and dysplipidemia [61]. This dietary habit was directly associated with the increased cardiometabolic risk profile, inflammatory markers and clinical severity of PsO [61]. On the contrary, PsO patients showed lower adherence to the Mediterranean diet, a popular and effective anti-oxidant diet, which was inversely correlated with inflammatory markers and PsO severity [62]. Since none of the single food components show to exert specific effects on the pathogenesis of PsO, it is reasonable to sustain that the biological anti-psoriatic effect is exerted by the food pattern, in other words, by the diet.

However, single foods in a diet should be carefully chosen in terms of nutrient richness and quality; for example, dietary lipids are essential to maintain cutaneous homeostasis and modulate skin immune and endocrine systems [62][63]. The composition of fatty acids (FAs) in dietary lipids significantly differs among dietary patterns. In the western diet, there is a very high intake of calories derived from fried products, butter and processed meat to the disadvantage of fish, nuts, fruits and vegetables. As such, saturated fatty acid (SFA) intake is elevated through the consumption of meat, butter and palm oil, while the intake of n-3 PUFAs, such as α-linolenic acid (18:3), eicosapentaenoic acid (EPA; 20:5) and docosahexaenoic acid (DHA; 22:6), which can be found in fish and nuts, is low. This fatty acid profile contributes to the negative health outcomes associated with the western diet by increasing the risk of dyslipidemia, obesity, diabetes or cardiovascular diseases, as well as total mortality [64].

Dietary SFAs represent a major risk factor for PsO exacerbation, even independently of obesity. In PsO patients, the serum levels of free FAs were associated with disease severity [65]. Furthermore, by introducing SFAs in the diet elicited a psoriatic flare in mice, suggesting the prominent pro-inflammatory role exerted by the western diet [65].

Interestingly, n-3 PUFAs play a key anti-inflammatory role in rodents (i.e., mice and rats), as well as in humans. Interestingly, PASI inversely correlates with the serum level of n-3 PUFA, and the SFA/unsaturated FA ratio increases with the duration of the disease [66].

2.1. Effects of Western Diet and Psoriasis on Microbiota

The perturbation of gut and/or skin microbiota may trigger systemic inflammation or even a flare of a pre-existent inflammatory condition (i.e., PsO) through pathobiont colonies increase [49][53][54][67][68]. During cutaneous inflammation, antimicrobial peptide release becomes less effective, and the interaction between bacteria and immune system, more frequent, thus acting as inflammatory triggers (i.e., *Staphylococcus aureus*) [69]. PsO patients exhibited a depletion of *Corynebacterium* spp., *Lactobacillus* spp., *Burkholderis* spp. and *Propionibacterium acnes* in cutaneous microbiota, as well as *Faecalibacterium prausnitzii* and *Akkermansia muciniphila* in gut microbiota. Conversely, Firmicutes and Actinobacteria spp. proliferated in the gut mucosa, reducing the pool of microbes capable of producing short chain fatty acids (SCFAs) [70][71][72]. Thus, microbiota represent the living, dynamic filter of dietetic nutrients, and its unbalance may have pro-inflammatory effects. This idea received a proof of concept with the clinical study by Deng et al., in which they described the beneficial role of specific probiotics (*Bifidobacterium infantis 35,624* and *Lactobacillus pentosus GMNL-77*) in decreasing imiquimod(IMQ)-induced psoriasiform eczema and its systemic inflammation (i.e., TNF-α and IL-6) [73][74][75].

Several studies suggested the influence of environmental factors such as dietary composition and, in particular, the western diet on microbial community and function [76][77][78]. The western diet was associated with intestinal barrier disruption and gut dysbiosis with an altered profile of bacterially produced metabolites, resulting in metabolic endotoxemia, immune system deregulation and systemic inflammation [60][79].

Since the IL-17/Il-23 pathway represents a bridge between innate and adaptive immunity against microbes, its modulation by nutrients is of particular interest. With specific regards to psoriasis, in a recent study in an IL-23–mediated model of PsO and PsA, Shi et al. revealed that a short-term western diet intake exacerbated both intestinal dysbiosis as well as psoriasis-like skin and joint inflammation [49]. Assuming that diet and inflammation may influence gut dysbiosis, they proved that, by switching from the western to a normal diet or even treating with broad spectrum antibiotics, IL-23-induced skin and joint inflammation mitigated. Furthermore, fecal microbiota transplantation from western-diet-fed donors into mice pretreated with broad-spectrum antibiotics revealed that gut microbiota triggered γδ T-cell infiltration into the dermis. Thus, microbiota modulation may be the key to also improve drug response in psoriatic patients.

The high-fat diet (HFD), as well as the western diet, was associated with lower microbial production of SCFAs, including butyrate, propionate and acetate, which are fermentation products of dietary fibers produced in the colon and are able to exert systemic effects, including at the skin level. Interestingly, SCFAs can be also produced by commensal bacteria in the skin [79]. A protective role of SCFAs against PsO was shown by several lines of evidence. SCFAs are able to (1) promote T-reg differentiation, activation and function; (2) inhibit the intestinal dendritic-cell production of IL-23 while inducing the expression of anti-inflammatory genes; (3) reduce skin inflammation in a mouse model of PsO, as well as downregulate IL-17 expression, and induce IL-10 and Foxp3 expression in animal and human psoriatic skin lesions [80].

3. How Lipids Influence Immune System Responses

3.1. Inflammasomes

Several studies demonstrated that macronutrients typical of the western diet, including SFAs, are able to induce and/or amplify pro-inflammatory responses involved in PsO development and progression [81][82][83]. Interestingly, IMQ-treated mice subjected to a HFD presented more severe clinical and histological (micro-abscesses and scaling) PsO than the ones following a regular diet. The HFD was responsible for the pathological activation of the nucleotide-binding domain, leucine-rich repeats containing family, pyrin domain-containing-3 (NLRP3) inflammasome. Inflammasomes are cytoplasmic multiprotein complexes for intracellular signaling that activate IL-1β via caspase-1, in response to different triggers (i.e., trauma or infections). Inflammasome activation was linked to the pathogenesis of metabolic and cardiovascular disease and is genetically associated with PsO [84]. Recent findings reported evidence of NLRP3 inflammasome activation in peripheral blood cells in PsO patients, in parallel with increased caspase-1 reactivity and serum levels of inflammasome-generated IL-1β and IL-18 [85]. TNF-α inhibitors are capable to turn off the inflammasome, as testified by the decreased plasmatic levels of IL-1β [85], thus suggesting a role of TNF-α-mediated NLRP3 inflammasome activation in patients with PsO and its contribution to systemic inflammation. In imiquimod(IMQ) mice, the HFD, but not the regular diet, increased the expression of activated caspase-1 and IL-1β in the skin. The HFD is also a strong activator of the IL-17 pathway, as testified by higher levels of IL-17A in both the dermis and serum of IMQ-treated mice.

References

1. Hawro, T.; Hawro, M.; Zalewska-Janowska, A.; Weller, K.; Metz, M.; Maurer, M. Pruritus and sleep disturbances in patients with psoriasis. Arch. Dermatol. Res. 2020, 312, 103–111.
2. Mostaghimi, L.; Hetzel, S. Insomnia and other sleep complaints in inflammatory versus noninflammatory skin disorders: An observational case-control study. Int. J. Dermatol. 2019, 58, 976–981.
3. Kabeloglu Ilbay, V.; Tas, B.; Altuntas, M.; Atakli, H.D.; Soysal, A. Risk of Obstructive Sleep Apnea Syndrome in Psoriasis Patients. Arch. Iran Med. 2019, 22, 137–143.
4. Saçmacı, H.; Gürel, G. Sleep disorders in patients with psoriasis: A cross-sectional study using non-polysomnographical methods. Sleep Breath. 2019, 23, 893–898.
5. Jensen, P.; Zachariae, C.; Skov, L.; Zachariae, R. Sleep disturbance in psoriasis: A case-controlled study. Br. J. Dermatol. 2018, 179, 1376–1384.
6. Gowda, S.; Goldblum, O.M.; McCall, W.V.; Feldman, S.R. Factors affecting sleep quality in patients with psoriasis. J. Am. Acad. Dermatol. 2010, 63, 114–123.
7. Hirotsu, C.; Rydlewski, M.; Araújo, M.S.; Tufik, S.; Andersen, M.L. Sleep Loss and Cytokines Levels in an Experimental Model of Psoriasis. PLoS ONE 2012, 7, e51183.
8. Henry, A.L.; Chisholm, A.; Carter, L.A.; Bundy, C.; Griffiths, C.E.; Kyle, S.D. The relationship between sleep disturbance, symptoms and daytime functioning in psoriasis: A prospective study integrating actigraphy and experience sampling methodology. Sleep Med. 2020, 72, 144–149.
9. Thaçi, D.; Galimberti, R.; Amaya-Guerra, M.; Rosenbach, T.; Robertson, D.; Pedersen, R.; Yang, S.; Kuligowski, M.; Boggs, R. Improvement in aspects of sleep with etanercept and optional adjunctive topical therapy in patients with moderate-to-severe psoriasis: Results from the PRISTINE trial. J. Eur. Acad. Dermatol. Venereol. 2014, 28, 900–906.
10. Strober, B.E.; Sobell, J.M.; Duffin, K.C.; Bao, Y.; Guérin, A.; Yang, H.; Goldblum, O.; Okun, M.M.; Mulani, P.M. Sleep quality and other patient-reported outcomes improve after patients with psoriasis with suboptimal response to other systemic therapies are switched to adalimumab: Results from PROGRESS, an open-label Phase IIIB trial. Br. J. Dermatol. 2012, 167, 1374–1381.
11. Egeberg, A.; Khalid, U.; Gislason, G.; Mallbris, L.; Skov, L.; Hansen, P.R. Psoriasis and Sleep Apnea: A Dan.ish Nationwide Cohort Study. J. Clin. Sleep Med. 2016, 12, 663–671.
12. Yang, Y.-W.; Kang, J.-H.; Lin, H.-C. Increased risk of psoriasis following obstructive sleep apnea: A longitudinal population-based study. Sleep Med. 2012, 13, 285–289.
13. Cohen, J.M.; Jackson, C.; Li, T.Y.; Wu, S.; Qureshi, A.A. Sleep disordered breathing and the risk of psoriasis among US women. Arch. Dermatol. Res. 2015, 307, 433–438.

14. Vgontzas, A.N.; Zoumakis, E.; Lin, H.-M.; Bixler, E.O.; Trakada, G.; Chrousos, G.P. Marked Decrease in Sleepiness in Patients with Sleep Apnea by Etanercept, a Tumor Necrosis Factor-? Antagonist. J. Clin. Endocrinol. Metab. 2004, 89, 4409–4413.
15. Chiu, H.-Y.; Hsieh, C.-F.; Chiang, Y.-T.; Tsai, Y.-W.; Huang, W.-F.; Li, C.-Y.; Wang, T.-S.; Tsai, T.-F. Concomitant Sleep Disorders Significantly Increase the Risk of Cardiovascular Disease in Patients with Psoriasis. PLoS ONE 2016, 11, e0146462.
16. Karaca, S.; Fidan, F.; Erkan, F.; Nural, S.; Pinarcı, T.; Gunay, E.; Unlu, M. Might psoriasis be a risk factor for obstructive sleep apnea syndrome? Sleep Breath 2013, 17, 275–280.
17. Shalom, G.; Dreiher, J.; Cohen, A. Psoriasis and obstructive sleep apnea. Int. J. Dermatol. 2016, 55, e579–e584.
18. Haugeberg, G.; Hoff, M.; Kavanaugh, A.; Michelsen, B. Psoriatic arthritis: Exploring the occurrence of sleep disturbances, fatigue, and depression and their correlates. Arthritis Res. Ther. 2020, 22, 1–10.
19. Luca, M.; Luca, A.; Musumeci, M.L.; Fiorentini, F.; Micali, G.; Calandra, C. Psychopathological Variables and Sleep Quality in Psoriatic Patients. Int. J. Mol. Sci. 2016, 17, 1184.
20. Henry, A.L.; Kyle, S.D.; Chisholm, A.; Griffiths, C.E.M.; Bundy, C. A cross-sectional survey of the nature and correlates of sleep dis-turbance in people with psoriasis. Br. J. Dermatol. 2017, 177, 1052–1059.
21. Kaaz, K.; Szepietowski, J.C.; Matusiak, Ł. Influence of Itch and Pain on Sleep Quality in Atopic Dermatitis and Psoriasis. Acta Derm. Venereol. 2019, 99, 175–180.
22. Gupta, M.A.; Simpson, F.C.; Vujcic, B.; Gupta, A.K. Obstructive sleep apnea and dermatologic disorders. Clin. Dermatol. 2017, 35, 319–327.
23. Walia, H.K.; Mehra, R. Overview of Common Sleep Disorders and Intersection with Dermatologic Conditions. Int. J. Mol. Sci. 2016, 17, 654.
24. Papadavid, E.; Dalamaga, M.; Vlami, K.; Koumaki, D.; Gyftopoulos, S.; Christodoulatos, G.S.; Papiris, S.; Rigopoulos, D. Psoriasis is associated with risk of obstructive sleep apnea independently from metabolic parameters and other comorbidities: A large hospital-based case-control study. Sleep Breath. 2017, 21, 949–958.
25. Wong, I.T.Y.; Chandran, V.; Li, S.; Gladman, D.D. Sleep Disturbance in Psoriatic Disease: Prevalence and Associated Factors. J. Rheumatol. 2017, 44, 1369–1374.
26. Melikoglu, M. Sleep Quality and its Association with Disease Severity in Psoriasis. Eurasian J. Med. 2017, 49, 124–127.
27. Gezer, O.; Batmaz, I.; Sariyildiz, M.A.; Sula, B.; Ucmak, D.; Bozkurt, M.; Nas, K. Sleep quality in patients with psoriatic arthritis. Int. J. Rheum. Dis. 2017, 20, 1212–1218.

28. Tas, B.; Kabeloglu, V.; Soysal, A.; Atakli, D. Sleep Quality in Psoriasis Patients and Its Relations with Possible Affecting Factors. Med. Bull. Sisli Hosp. 2020, 54, 181–187.
29. Hirotsu, C.; Nogueira, H.; Albuquerque, R.G.; Tomimori, J.; Tufik, S.; Andersen, M.L. The bidirectional interactions between psoriasis and obstructive sleep apnea. Int. J. Dermatol. 2015, 54, 1352–1358.
30. Henry, A.; Bundy, C.; Kyle, S.; Griffiths, C.E.M.; Chisholm, A. Understanding the experience of sleep disturbance in psoriasis: A qualitative exploration using the Common-Sense Model of Self-Regulation. Br. J. Dermatol. 2019, 180, 1397–1404.
31. Papadavid, E.; Vlami, K.; Dalamaga, M.; Giatrakou, S.; Theodoropoulos, K.; Gyftopoulos, S.; Stavrianeas, N.; Papiris, S.; Rigopoulos, D. Sleep apnea as a comorbidity in obese psoriasis patients: A cross-sectional study. Do psoriasis characteristics and metabolic parameters play a role? J. Eur. Acad. Dermatol. Venereol. 2013, 27, 820–826.
32. Ger, T.-Y.; Fu, Y.; Chi, C.-C. Bidirectional Association Between Psoriasis and Obstructive Sleep Apnea: A Systematic Review and Meta-Analysis. Sci. Rep. 2020, 10, 5931.
33. Maari, C.; Bolduc, C.; Nigen, S.; Marchessault, P.; Bissonnette, R. Effect of adalimumab on sleep parameters in patients with pso-riasis and obstructive sleep apnea: A randomized controlled trial. J. Dermatol. Treat. 2014, 25, 57–60.
34. Selmi, C.; Montano, N.; Furlan, R.; Keen, C.L.; Gershwin, M.E. Inflammation and Oxidative Stress in Obstructive Sleep Apnea Syndrome. Exp. Biol. Med. 2007, 232, 1409–1413.
35. E Lewis, P.; Emasealu, O.V.; Rohrbeck, P.; Hu, Z. Risk of type II diabetes and hypertension associated with chronic insomnia among active component, U.S. Armed Forces, 1998–2013. MSMR 2014, 21, 6–13.
36. Loke, Y.K.; Brown, J.W.; Kwok, C.S.; Niruban, A.; Myint, P.K. Association of obstructive sleep apnea with risk of serious cardio-vascular events: A systematic review and meta-analysis. Circ. Cardiovasc. Qual. Outcomes 2012, 5, 720–728.
37. Gupta, M.A.; Simpson, F.C. Obstructive Sleep Apnea and Psychiatric Disorders: A Systematic Review. J. Clin. Sleep Med. 2015, 11, 165–175.
38. Drager, L.F.; Togeiro, S.M.; Polotsky, V.Y.; Lorenzi-Filho, G. Obstructive sleep apnea: A cardiometabolic risk in obesity and the metabolic syndrome. J. Am. Coll. Cardiol. 2013, 62, 569–576.
39. Jean-Louis, G.; Zizi, F.; Clark, L.T.; Brown, C.D.; McFarlane, S.I. Obstructive Sleep Apnea and Cardiovascular Disease: Role of the Metabolic Syndrome and Its Components. J. Clin. Sleep Med. 2008, 4, 261–272.

40. Besedovsky, L.; Lange, T.; Haack, M. The Sleep-Immune Crosstalk in Health and Disease. Physiol. Rev. 2019, 99, 1325–1380.
41. Garbarino, S.; Lanteri, P.; Bragazzi, N.L.; Magnavita, N.; Scoditti, E. Role of sleep deprivation in immune-related disease risk and outcomes. Commun. Biol. 2021, 4, 1304.
42. Imagawa, S.; Yamaguchi, Y.; Higuchi, M.; Neichi, T.; Hasegawa, Y.; Mukai, H.Y.; Suzuki, N.; Yamamoto, M.; Nagasawa, T. Levels of vascular endothelial growth factor are elevated in patients with obstructive sleep apnea–hypopnea syndrome. Blood 2001, 98, 1255–1257.
43. Rosenberger, C.; Solovan, C.; Rosenberger, A.D.; Jinping, L.; Treudler, R.; Frei, U.; Eckardt, K.-U.; Brown, L.F. Upregulation of Hypoxia-Inducible Factors in Normal and Psoriatic Skin. J. Investig. Dermatol. 2007, 127, 2445–2452.
44. Baran, A.; Flisiak, I.; My´sliwiec, H.; Chodynicka, B. Role of adiponectin in psoriasis. Dermatol. Rev. 2010, 97, 413–416.
45. Yasuda, K.-I.; Ishiuji, Y.; Endo, T.; Tanito, K.; Kamide, R.; Nobeyama, Y.; Asahina, A. Cyclosporine Improves Sleep Quality in Patients with Atopic Dermatitis. Dermatol. Ther. 2020, 10, 1359–1369.
46. Krajewska-Włodarczyk, M.; Owczarczyk-Saczonek, A.; Placek, W. Sleep disorders in patients with psoriatic arthritis and pso-riasis. Reumatologia 2018, 56, 301–306.
47. Ransom, J.; Morgan, P.J.; McCaffery, P.J.; Stoney, P.N. The rhythm of retinoids in the brain. J. Neurochem. 2014, 129, 366–376.
48. Shi, Z.; Wu, X.; Rocha, C.S.; Rolston, M.; Garcia-Melchor, E.; Huynh, M.; Nguyen, M.; Law, T.; Haas, K.N.; Yamada, D.; et al. Short-Term Western Diet Intake Promotes IL-23–Mediated Skin and Joint Inflammation Accompanied by Changes to the Gut Microbiota in Mice. J. Investig. Dermatol. 2021, 141, 1780–1791.
49. Shi, Z.; Wu, X.; Yu, S.; Huynh, M.; Jena, P.K.; Nguyen, M.; Wan, Y.-J.Y.; Hwang, S.T. Short-Term Exposure to a Western Diet Induces Psoriasiform Dermatitis by Promoting Accumulation of IL-17A–Producing γδ T Cells. J. Investig. Dermatol. 2020, 140, 1815–1823.
50. Damiani, G.; Bragazzi, N.; McCormick, T.S.; Pigatto, P.D.M.; Leone, S.; Pacifico, A.; Tiodorovic, D.; Di Franco, S.; Alfieri, A.; Fiore, M. Gut microbiota and nutrient interactions with skin in psoriasis: A comprehensive review of animal and human studies. World J. Clin. Cases 2020, 8, 1002–1012.
51. Smolensky, M.H.; Portaluppi, F.; Manfredini, R.; Hermida, R.C.; Tiseo, R.; Sackett-Lundeen, L.L.; Haus, E.L. Diurnal and twenty-four hour patterning of human diseases: Acute and chronic common and uncommon medical conditions. Sleep Med. Rev. 2015, 21, 12–22.
52. Paolino, G.; Buratta, S.; Mercuri, S.R.; Pellegrino, R.M.; Urbanelli, L.; Emiliani, C.; Bertuccini, L.; Iosi, F.; Huber, V.; Brianti, P.; et al. Lipidic Profile Changes in Exosomes and Microvesicles

Derived From Plasma of Monoclonal Antibody-Treated Psoriatic Patients. Front Cell Dev Biol. 2022, 10, 923769.

53. Damiani, G.; Franchi, C.; Pigatto, P.; Altomare, A.; Pacifico, A.; Petrou, S.; Leone, S.; Pace, M.C.; Fiore, M. Outcomes assessment of hepatitis C virus-positive psoriatic patients treated using pegylated interferon in combination with ribavirin compared to new Direct-Acting Antiviral agents. World J. Hepatol. 2018, 10, 329–336.
54. Gisondi, P.; Cazzaniga, S.; Chimenti, S.; Giannetti, A.; Maccarone, M.; Picardo, M.; Girolomoni, G.; Naldi, L.; Psocare Study Group. Metabolic abnormalities associated with initiation of systemic treatment for psoriasis: Evidence from the Italian Psocare Registry. J. Eur. Acad. Dermatol. Venereol. 2013, 27, e30–e41.
55. Damiani, G.; Cazzaniga, S.; Conic, R.R.; Naldi, L. Psocare Registry Network. Pruritus Characteristics in a Large Italian Cohort of Psoriatic Patients. J. Eur. Acad. Dermatol. Venereol. 2019, 33, 1316–1324.
56. Herbert, D.; Franz, S.; Popkova, Y.; Anderegg, U.; Schiller, J.; Schwede, K.; Lorz, A.; Simon, J.C.; Saalbach, A. High-Fat Diet Exacerbates Early Psoriatic Skin Inflammation Independent of Obesity: Saturated Fatty Acids as Key Players. J. Investig. Dermatol. 2018, 138, 1999–2009.
57. Honda, T.; Kabashima, K. Current understanding of the role of dietary lipids in the pathophysiology of psoriasis. J. Dermatol. Sci. 2019, 94, 314–320.
58. Carrera-Bastos, P.; Fontes-Villalba, M.; O'Keefe, J.H.; Lindeberg, S.; Cordain, L. The western diet and lifestyle and diseases of civilization. Res. Rep. Clin. Cardiol. 2011, 2, 15–35.
59. Cordain, L.; Eaton, S.B.; Sebastian, A.; Mann, N.; Lindeberg, S.; Watkins, B.A.; O'Keefe, J.H.; Brand-Miller, J. Origins and evolution of the Western diet: Health implications for the 21st century. Am. J. Clin. Nutr. 2005, 81, 341–354.
60. García-Montero, C.; Fraile-Martínez, O.; Gómez-Lahoz, A.M.; Pekarek, L.; Castellanos, A.J.; Noguerales-Fraguas, F.; Coca, S.; Guijarro, L.G.; García-Honduvilla, N.; Asúnsolo, A.; et al. Nutritional Components in Western Diet Versus Mediterranean Diet at the Gut Microbiota-Immune System Interplay. Implications for Health and Disease. Nutrients 2021, 13, 699.
61. Barrea, L.; Macchia, P.E.; Tarantino, G.; Di Somma, C.; Pane, E.; Balato, N.; Napolitano, M.; Colao, A.; Savastano, S. Nutrition: A key environmental dietary factor in clinical severity and cardio-metabolic risk in psoriatic male patients evaluated by 7-day food-frequency questionnaire. J. Transl. Med. 2015, 13, 303.
62. Barrea, L.; Balato, N.; Di Somma, C.; Macchia, P.E.; Napolitano, M.; Savanelli, M.C.; Esposito, K.; Colao, A.; Savastano, S. Nutrition and psoriasis: Is there any association between the severity of the disease and adherence to the Mediterranean diet? J. Transl. Med. 2015, 13, 18.

63. Kocic, H.; Damiani, G.; Stamenkovic, B.; Tirant, M.; Jovic, A.; Tiodorovic, D.; Peris, K. Dietary compounds as potential modulators of microRNA expression in psoriasis. Ther. Adv. Chronic Dis. 2019, 10, 2040622319864805.

64. Billingsley, H.E.; Carbone, S.; Lavie, C.J. Dietary Fats and Chronic Noncommunicable Diseases. Nutrients 2018, 10, 1385.

65. Yazdanpanah, M.J.; Vahabi-Amlashi, S.; Nematy, M.; Shaelaei, N.; Mohajeri, S.A.R.; Tafazzoli, Z. Association of serum lipid profiles and dietary intakes of vitamin E and fiber with psoriasis severity. Caspian J. Intern. Med. 2021, 12, 606–612.

66. Myśliwiec, H.; Baran, A.; Harasim-Symbor, E.; Myśliwiec, P.; Milewska, A.J.; Chabowski, A.; Flisiak, I. Serum fatty acid profile in psoriasis and its comorbidity. Arch. Dermatol. Res. 2017, 309, 371–380.

67. Zákostelská, Z.; Málková, J.; Klimešová, K.; Rossmann, P.; Hornová, M.; Novosádová, I.; Stehlíková, Z.; Kostovčík, M.; Hudcovic, T.; Štepánková, R.; et al. Intestinal microbiota promotes psoriasis-like skin inflammation by enhancing Th17 response. PLoS ONE 2016, 11, e0159539.

68. Stehlikova, Z.; Kostovcikova, K.; Kverka, M.; Rossmann, P.; Dvorak, J.; Novosadova, I.; Kostovcik, M.; Coufal, S.; Srutkova, D.; Prochazkova, P.; et al. Crucial Role of Microbiota in Experimental Psoriasis Revealed by a Gnotobiotic Mouse Model. Front. Microbiol. 2019, 10, 236.

69. Kabashima, K.; Honda, T.; Ginhoux, F.; Egawa, G. The immunological anatomy of the skin. Nat. Rev. Immunol. 2017, 19, 19–30.

70. Fyhrquist, N.; Muirhead, G.; Prast-Nielsen, S.; Jeanmougin, M.; Olah, P.; Skoog, T.; Jules-Clement, G.; Feld, M.; Barrientos-Somarribas, M.; Sinkko, H.; et al. Microbe-host interplay in atopic dermatitis and psoriasis. Nat. Commun. 2019, 10, 4703.

71. Hidalgo-Cantabrana, C.; Gómez, J.; Delgado, S.; Requena-López, S.; Queiro-Silva, R.; Margolles, A.; Coto, E.; Sánchez, B.; Coto-Segura, P. Gut microbiota dysbiosis in a cohort of patients with psoriasis. Br. J. Dermatol. 2019, 181, 1287–1295.

72. Chen, Y.; Ho, H.J.; Tseng, C.; Lai, Z.; Shieh, J.-J.; Wu, C.-Y. Intestinal microbiota profiling and predicted metabolic dysregulation in psoriasis patients. Exp. Dermatol. 2018, 27, 1336–1343.

73. Deng, Y.; Fang, Z.; Cui, S.; Zhao, J.; Zhang, H.; Chen, W.; Lu, W. Evaluation of probiotics for inhibiting hyperproliferation and in-flammation relevant to psoriasis in vitro. J. Funct. Foods 2021, 81, 104433.

74. Chen, Y.-H.; Wu, C.-S.; Chao, Y.-H.; Lin, C.-C.; Tsai, H.-Y.; Li, Y.-R.; Chen, Y.Z.; Tsai, W.-H.; Chen, Y.-K. Lactobacillus pentosus GMNL-77 inhibits skin lesions in imiquimod-induced psoriasis-like mice. J. Food Drug Anal. 2017, 25, 559–566.

75. Groeger, D.; O'Mahony, L.; Murphy, E.F.; Bourke, J.F.; Dinan, T.G.; Kiely, B.; Shanahan, F.; Quigley, E.M. Bifidobacterium infantis35624 modulates host inflammatory processes beyond the gut. Gut Microbes 2013, 4, 325–339.
76. Hsu, D.K.; Fung, M.A.; Chen, H.-L. Role of skin and gut microbiota in the pathogenesis of psoriasis, an inflammatory skin disease. Med. Microecol. 2020, 4, 100016.
77. Wang, X.; Li, Y.; Wu, L.; Xiao, S.; Ji, Y.; Tan, Y.; Jiang, C.; Zhang, G. Dysregulation of the gut-brain-skin axis and key overlapping inflammatory and immune mechanisms of psoriasis and depression. Biomed. Pharmacother. 2021, 137, 111065.
78. Martinez, K.B.; Leone, V.; Chang, E.B. Western diets, gut dysbiosis, and metabolic diseases: Are they linked? Gut Microbes 2017, 8, 130–142.
79. Malesza, I.J.; Malesza, M.; Walkowiak, J.; Mussin, N.; Walkowiak, D.; Aringazina, R.; Bartkowiak-Wieczorek, J.; Mądry, E. High-Fat, Western-Style Diet, Systemic Inflammation, and Gut Microbiota: A Narrative Review. Cells 2021, 10, 3164.
80. Kanda, N.; Hoashi, T.; Saeki, H. Nutrition and Psoriasis. Int. J. Mol. Sci. 2020, 21, 5405.
81. Endo, Y.; Asou, H.K.; Matsugae, N.; Hirahara, K.; Shinoda, K.; Tumes, D.J.; Tokuyama, H.; Yokote, K.; Nakayama, T. Obesity Drives Th17 Cell Differentiation by Inducing the Lipid Metabolic Kinase, ACC1. Cell Rep. 2015, 12, 1042–1055.
82. Stelzner, K.; Herbert, D.; Popkova, Y.; Lorz, A.; Schiller, J.; Gericke, M.; Klöting, N.; Blüher, M.; Franz, S.; Simon, J.C.; et al. Free fatty acids sensitize dendritic cells to amplify TH1/TH17-immune responses. Eur. J. Immunol. 2016, 46, 2043–2053.
83. Shimoura, N.; Nagai, H.; Fujiwara, S.; Jimbo, H.; Nishigori, C. Exacerbation and Prolongation of Psoriasiform Inflammation in Diabetic Obese Mice: A Synergistic Role of CXCL5 and Endoplasmic Reticulum Stress. J. Investig. Dermatol. 2018, 138, 854–863.
84. Olsen, M.B.; Gregersen, I.; Sandanger, Ø.; Yang, K.; Sokolova, M.; Halvorsen, B.E.; Gullestad, L.; Broch, K.; Aukrust, P.; Louwe, M.C. Targeting the Inflammasome in Cardiovascular Disease. JACC Basic Transl. Sci. 2021, 7, 84–98.
85. Verma, D.; Fekri, S.Z.; Sigurdardottir, G.; Eding, C.B.; Sandin, C.; Enerbäck, C. Enhanced Inflammasome Activity in Patients with Psoriasis Promotes Systemic Inflammation. J. Investig. Dermatol. 2021, 141, 586–595.e5.