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A Review of the Role of Keratinocytes in Psoriasis

Srinika Allala

Abstract: Psoriasis is a chronic inflammatory skin disorder characterized by accelerated keratinocyte proliferation, disrupted epidermal differentiation, and persistent inflammation. While psoriasis has traditionally been viewed as an immune mediated disease, recent studies demonstrate that early pathogenic events arise within keratinocytes, where metabolic, signaling, and gene regulatory alterations occur prior to full immune activation (Ni & Lai, 2020; Huang et al., 2024; Zhou et al., 2022). This paper aims to examine how keratinocyte intrinsic molecular changes initiate psoriasis, how cytokine signaling sustains keratinocyte hyperproliferation, and how these mechanisms inform current therapeutic strategies. Evidence from molecular, genetic, and experimental studies shows that altered metabolic enzymes, including LPCAT1 and FBP1, activate proliferative and inflammatory signaling pathways such as STAT3 and NF κB and promote transcriptional reprogramming that favors keratinocyte growth over differentiation (Huang et al., 2024; Zhou et al., 2022; Zhang et al., 2024). Cytokine signaling through the TNF α, IL 23, and IL 17 axis further amplifies keratinocyte activation, with keratinocytes acting as both targets and producers of inflammatory mediators that reinforce disease progression (Griffiths et al., 2021; Zhou et al., 2022). Clinical studies demonstrate that biologic therapies targeting TNF α, IL 17, and IL 23, as well as emerging metabolic and natural compound based interventions, effectively reduce keratinocyte hyperproliferation and inflammation (Griffiths et al., 2021; Alimujiang et al., 2025; Zhang et al., 2024). Together, these findings support a model in which psoriasis originates from keratinocyte driven molecular disturbances that interact with cytokine mediated immune responses to sustain chronic disease.

Psoriasis is a chronic inflammatory skin disorder characterized by accelerated keratinocyte growth, disrupted epidermal differentiation, and persistent inflammation. Although historically viewed as an immune-driven disease, recent molecular studies demonstrate that early pathogenic events originate within keratinocytes themselves, where metabolic, signaling, and gene regulatory alterations precede full immune activation (Ni & Lai, 2020; Huang et al., 2024; Zhou et al., 2022). These intrinsic disturbances prime keratinocytes to proliferate abnormally and release pro-inflammatory mediators, creating local conditions that subsequently recruit and amplify immune responses. Understanding these keratinocyte-initiated mechanisms is essential for explaining how psoriasis develops and why it becomes a self-perpetuating cycle of epidermal overgrowth and inflammation.

Molecular Drivers of Psoriasis

Psoriasis is primarily initiated by metabolic, signaling, and gene regulatory alterations within keratinocytes, which often arise before the immune system becomes fully activated (Zhou et al, 2022). Keratinocytes are not simply passive targets of inflammation; instead, they actively produce inflammatory mediators that accelerate their own proliferation and disrupt epidermal homeostasis (Ni & Lai, 2020). These early molecular disturbances reposition keratinocytes as primary initiators of disease. As these disruptions accumulate, the keratinocyte cell cycle shortens dramatically, from approximately twenty-eight days to just a few days, resulting in rapid epidermal thickening and formation of characteristic psoriatic plaques.

Multiple studies have identified specific pathways that drive this abnormal growth. One example is the overactivity of LPCAT1, a lipid metabolism enzyme whose elevation in psoriatic keratinocytes activates STAT3 and NF-κB signaling, two major regulators of proliferation, survival, and inflammatory gene expression (Huang et al., 2024). LPCAT1 also increases glucose uptake through GLUT3, supplying metabolic fuel for hyperproliferative keratinocytes (Huang et al., 2024). These findings illustrate how metabolic changes directly promote both excessive growth and inflammation.

Zhou et al. (2022) further show that transcription factors and noncoding RNAs reshape gene expression programs in psoriatic keratinocytes. These regulatory changes amplify expression of genes involved in proliferation while suppressing differentiation pathways, disrupting normal epidermal maturation and accelerating plaque development. Their results indicate that keratinocytes undergo coordinated transcriptional reprogramming that enables them to maintain a highly proliferative and inflammatory state. Collectively, these studies demonstrate that psoriasis originates from keratinocyte-driven molecular disturbances that precede and initiate immune activation. Altered metabolism, dysregulated signaling pathways, and disrupted gene regulatory networks together push keratinocytes into continuous overgrowth while creating a pro-inflammatory environment that sustains disease progression.

Cytokines as Drivers of Psoriasis

Cytokine signaling is another central driver of keratinocyte hyperproliferation in psoriasis and results from genetic susceptibility and immune dysregulation. Cytokines are small signaling proteins secreted by immune and non-immune cells that regulate inflammation, cell growth, and tissue homeostasis, playing a key role in coordinating the immune response in psoriasis (Griffiths et al., 2021). Variants affecting immune regulatory pathways can heighten cytokine production and shift keratinocyte behavior from controlled growth to sustained activation (Griffiths et al., 2021). Central to this inflammatory response is the TNF-α / IL-23 / IL-17 axis. Cytokines within this network activate keratinocyte receptors and trigger intracellular signaling cascades such as

STAT3 and NF-κB, which in psoriasis remain chronically active (Griffiths et al., 2021; Huang et al., 2024). Persistent activation promotes keratinocyte proliferation, induces chemokine release, and recruits additional immune cells, reinforcing the inflammatory cycle.

Further evidence shows that IL-17 cytokines directly stimulate keratinocytes to produce antimicrobial peptides, chemokines, and inflammatory mediators (Lowes et al., 2014). IL-23 sustains pathogenic Th17 cells, which secrete IL-17A, IL-17F, and IL-22—cytokines that accelerate keratinocyte proliferation and impair normal differentiation (Hawkes et al., 2023). Zhou et al. (2022) also demonstrate that keratinocytes themselves produce cytokines such as IL-17C, IL-23, and IL-36, generating autocrine inflammatory loops that independently amplify their activation.

Genetic loss of IL36RN, which encodes the IL-36 receptor antagonist, removes an essential brake on IL-36 signaling. This leads to excessive cytokine and chemokine production, heightened neutrophil recruitment, and severe keratinocyte hyperproliferation—mechanisms linked to generalized pustular psoriasis (Frontiers in Immunology 2023; Bachelez 2022). These findings affirm that cytokine dysregulation operates at multiple levels and that keratinocytes actively contribute to sustaining chronic inflammation.

Clinical Treatments to Psoriasis

Therapeutic strategies for psoriasis focus on interrupting the molecular and immune-driven mechanisms that cause keratinocyte hyperproliferation. One key target is metabolic regulation within keratinocytes. FBP1, a critical enzyme in gluconeogenesis, controls keratinocyte proliferation and differentiation by regulating histone acetylation, which affects gene expression programs associated with growth and maturation (Zhang et al., 2024). In psoriatic skin, reduced FBP1 expression shifts keratinocyte metabolism toward glycolysis, providing energy that supports rapid proliferation, while increasing histone acetylation to promote pro-growth gene expression (Zhang et al., 2024). Experimental deletion of FBP1 in mouse models further intensified psoriasiform inflammation, highlighting its therapeutic potential as a molecular target for restoring normal epidermal growth (Zhang et al., 2024).

Natural compounds have also demonstrated potential in regulating both keratinocyte proliferation and inflammation. Apigenin, a plant-derived flavonoid, significantly reduced plaque severity, epidermal thickness, and inflammatory markers in psoriatic mouse models (Alimujiang et al., 2025). Functionally, Apigenin inhibits the CDK2/E2F2 cell cycle pathway, which controls keratinocyte proliferation and suppresses IL-17–mediated cytokine signaling, demonstrating dual efficacy in targeting keratinocyte-intrinsic growth and immune-mediated inflammation (Alimujiang et al., 2025).

Biologic therapies represent a major advancement in psoriatic treatment by targeting specific cytokines that drive disease. Unlike traditional systemic agents, biologics selectively block TNF-α, IL-17, or IL-23, disrupting the cytokine receptor–mediated signaling essential for keratinocyte activation (Griffiths et al., 2021). This includes anti-TNF agents that neutralize TNF-α, anti-IL-17 biologics that block IL-17A activity, and anti-IL-23 therapies that prevent IL-23–driven expansion of IL-17–producing T cells (Griffiths et al., 2021). Clinical trials demonstrate that these treatments achieve higher clearance rates, longer remission, and fewer systemic side effects than older therapies (Griffiths et al., 2021).

Evidence suggests that combining metabolic interventions with cytokine-targeting biologics may yield synergistic benefits (Zhang et al., 2024; Alimujiang et al., 2025). Restoring FBP1 activity or mimicking its effects could complement biologics by addressing both keratinocyte-intrinsic and immune-mediated drivers of disease.

Conclusion

Recent findings have redefined the understanding of psoriasis by demonstrating that keratinocyte metabolism, signaling, and cytokine interactions lie at the core of disease development. Reduced expression of FBP1 promotes glycolytic metabolism and increased histone acetylation, driving keratinocyte overgrowth, while experimental deletion of FBP1 markedly intensifies inflammation in mouse models (Zhang et al., 2024). Natural compounds such as Apigenin further support therapeutic innovation by suppressing keratinocyte proliferation and IL-17 signaling (Alimujiang et al., 2025). Clinical evidence shows that biologic therapies targeting TNF-α, IL-17, and IL-23 achieve superior outcomes compared to traditional systemic treatments (Griffiths et al., 2021). Collectively, research supports a shift toward precision therapies that treat both the metabolic and immunologic mechanisms sustaining psoriasis. Continued investigation into metabolic pathways, natural therapeutics, and advanced biologics may lead to more durable and personalized treatments (Zhang et al., 2024; Alimujiang et al., 2025; Griffiths et al., 2021).

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Understanding Neoblasts for Stem Cell Therapeutics

Abigail Robinson

Abstract: Stem cells are one of the most important cells within an organism when it comes to growth and healing. Due to the properties of stem cells, researchers have looked into them for regenerative medicine as a therapeutic resource for diseases and traumatic injuries. A recent avenue of regenerative medicine researched for this goal are induced pluripotent stem cells (iPSCs). iPSCs were developed due to low numbers of mature pluripotent stem cells in humans. In contrast, planarians are organisms that possess neoblasts, a multitude of pluripotent stem cells, throughout their lives which enables immense regenerative capabilities. Understanding the properties and mechanisms of neoblasts has equipped researchers with a foundation for the induction of pluripotency in human stem cells. This paper aims to summarize the current understanding of neoblasts and human stem cells and the challenges the field is undertaking with stem cell therapeutics.

Keywords: stem cells, neoblasts, reprogramming, pluripotency

According to the Health Resources & Services Administration, 13 people on the organ donation waiting list die each day (HRSA, 2025). There are currently over 100,000 people on the national waiting list for organ transplants, yet there were less than half that number of transplants performed in the year 2024 (HRSA, 2025). Given the disproportionate demand for organs to organ availability, researchers have been working towards other solutions. Regenerative medicine is a unique medical specialty because it harnesses the body's own healing properties and mechanisms to repair tissue or organ damage. This field is focused on developing therapeutics for aging, various diseases, such as cardiovascular diseases, organ failure, certain types of cancer, or injuries (Mao & Mooney, 2015; Kamath et al., 2023). A prominent research focus in regenerative medicine is stem cells due to their reparative function in human tissues and organs. Current regenerative research focuses on the development and application of induced pluripotent stem cells (iPSCs) through the investigation of other stem cells with the desired capabilities as a reference. (Cobellis & Romito, 2015; Cai et al., 2024). This paper details the properties of human and planarian stem cells, the current process and pitfalls for inducing human pluripotent stem cells.

Naturally Occurring Human Stem Cells

Stem cells are unspecialized cells in the body known for their self-renewal properties and unique ability to differentiate into other cells. They play a vital role by facilitating growth and repairing damage in organisms. Stem cells are characterized by the organ of origin or the developmental state in which they arose from (Chagastelles & Nardi, 2011; Dobrzyński et al., 2019; Bari et al., 2021). The earliest and most potent form of stem cells in human development is as a zygote. The zygote is a totipotent cell meaning it holds the capability to form a whole organism. From there, the zygote goes through more stages of cell division to develop the zygote into an embryo by generating features like the morula, blastocyst, embryonic membranes, and placenta (Chagastelles & Nardi, 2011). The embryo then develops into the fetus stage and, once it reaches maturity and is born, the cells have divided into a fully formed organism. Infants' stem cells still maintain a level of pluripotency, but differentiate often to facilitate growth resulting in a subset shift with adult stem cells overtaking the stem cell compartment in the human body (Chagastelles & Nardi, 2011; Dobrzyński et al., 2019). Adult stem cells are multipotent meaning they retain the ability to differentiate but are more limited in the options of what cells they can differentiate into. Adult stem cells can be found in a few differing tissues throughout the body like bone marrow and fat tissue. There are many different types of adult pluripotent stem cells depending on location and these different types have different ranges of cells that they can

differentiate into (Chagastelles & Nardi, 2011; Dobrzyński et al., 2019). Adult stem cells are essential for general growth and homeostatic repair of injured tissue in humans, however they are unable to respond to extreme traumas or organ failures and tend to decrease in pluripotency due to aging (Bari et al, 2022). To look into solutions for the shortcomings of adult stem cells, researchers focused on culturing embryonic stem cells (ESCs) which they derive from blastocysts in embryos (Brick et al., 2011; Gambardella et al., 2023). Embryonic stem cells are pluripotent, meaning they have the ability to differentiate into a variety of cell types. The pluripotency and proliferation of these cells is what made them so desirable for stem cell therapy. ESCs' self renewing abilities are regulated by various factors such as signalling pathways, cytokines, and transcription factors. Signaling pathway proteins carefully control stemness regulators through careful networks (Gambardella et al., 2023). Cytokines send messages to other factors such as signaling pathway proteins throughout the cell. For example, leukemia suppressing factor LIF triggers signaling pathway Jak-Stat3 which, in combination with BMP4, promotes pluripotency in the cell (Chen et al, 2022). Transcription factors, along with the previously mentioned pluripotency functions, also suppress differentiation genes. The transcription factors forming the pluripotency regulatory network (OCT4, SOX2, and NANOG) are integral to maintaining pluripotency. The knockdown of these genes via RNA interference results in the loss of the proliferative properties of the cell (Cobellis & Romito, 2015; Chen et al, 2022)). While culturing ESCs was a great step forward in stem cell research and innovation, the application and cultivation of cultured ESCs is both steeped in controversy and not easy to obtain leading stem cell researchers to look for new ways to develop this medicine.

Regenerative Properties of Planarians

A planarian, more specifically Schmidtea mediterranea, is a flatworm that is known for its remarkable regenerative abilities that allow them to regenerate nearly their entire bodies, including major organs like the brain. This ability is due to their special kind of stem cells known as neoblasts. Neoblasts make up 20-30% of a planarian's body (Chen, 2025). They are heterogeneous cells meaning there are multiple different types of this cell. A prominent single-cell analysis of neoblasts from 2014 puts these neoblast types into two main classes: sigma and zeta cells. Sigma neoblasts are pluripotent and proliferate in response to wounding. Sigma neoblasts have an extremely wide variety of differentiation capability that allows them to even regenerate other neoblast classes. Zeta neoblasts are specialized cells that are integral to maintenance of the epidermis. Zeta cells contribute to an abundance of mature cells. These different types of neoblasts have different functions within the neoblast. The sigma neoblasts are the cells that allow for regeneration (Raz et al., 2021; Chen, 2025). Unlike zeta neoblasts which are regulated by tissue specific transcription factors (TFs), sigma neoblasts as undifferentiated cells lack specific TFs and are instead maintained by chromatin remodelers which are less specialized and binding than the specific TFs. Evidence also strongly suggests that neoblasts default back to their undifferentiated pluripotent state in the absence of tissue specific TFs (Kratkiewicz et al., 2023). Neoblasts are vital to the regenerating process but they would be useless without the help of positional information. Positional information is the instructions for the neoblasts which conducts a prompt series of responses when triggered by amputation or injury that ensures the pain to be minimal and the regeneration efficient (Reddien, 2020; Chen 2025). These signals are received through cell to cell communication which is vital in proliferation, differentiation, and regeneration patterns (Chen & Lei, 2023). An example of this "response and regulation" dynamic through signaling is with the proteins Wnt and notum. They are both expressed in response to injury, but Wnt is a protein that signals regeneration while notum is Wnt's inhibitor yet is also controlled by Wnt signalling. These two proteins signal and balance each other to maintain homeostasis within the planarian (Petersen & Reddien, 2011). Planarians are a complex species with one of the highest capacities for regeneration. Another mechanism that allows specialized neoblasts to retain potency is dividing into asymmetric cell fates meaning that the two resulting daughter cells from division have two different cell fates. These abilities along with being one of the simplest multicellular organisms that clearly exhibits regeneration is the reason they stand out as a model for stem cell research (Goodarzi et al., 2015). While their biology differs greatly from humans, the Schmidtea mediterranea serves as an example of the fascinating regenerative abilities of stem cells.

Induced Pluripotent Stem Cells

There have been many attempts to utilize stem cells in a way reminiscent of neoblast regeneration. Researchers have looked into finding ways to enhance the pluripotent abilities of adult stem cells for therapeutic purposes for a long time. Originally, researchers had attempted to use embryonic stem cells for these purposes but ran into many issues. The biggest difficulties with using embryonic stem cells was ethical pushback and a lack of available embryonic stem cells since obtaining the stem cells from an embryo destroys the blastocyst and results in the inability for a fetus to form. ESCs have also displayed genetic instability (Chagastelles & Nardi, 2011; Kamath et al., 2023). A less controversial form of stem cell therapy following the ESCs are induced pluripotent stem cells (iPSC). These are cells that, rather than being naturally pluripotent like hESC or neoblasts, are somatic adult stem cells that are reprogrammed to be pluripotent. Typically the reprogramming process is made to imitate the natural developmental process in reverse, going from differentiated to undifferentiated. The main two sets of reprogramming genes for hiPSC are Oct4, Sox2, Klf4, and Myc & Oct4, Sox2, Nanog, and Lin28. The discovery of these combinations was a significant advancement in the development of iPSCs. The first combination was discovered by researchers Shinya Yamanaka and Kazutoshi Takahashi in 2006 when running an experiment to induce pluripotency in somatic mouse cells using retroviral gene delivery, a process in which outside genes are introduced to the original through a virus (Kamath et al., 2023; Cai et al., 2024). It was then proven a year later that the first gene combination along with a second ,slightly different, one, discovered by biologist James Thomson, were also applicable in the dedifferentiating of human fibroblasts into iPSCs solidifying these two combinations as the blueprints for reprogramming somatic cells into hiPSCs (Kamath et al., 2023; Cai et al., 2024). Induced Pluripotent Stem Cells are still a work-in-progress, however. These two sets of reprogramming genes both pose an issue due to their inclusion of Myc or Lin28, both of which are essential for cell reprogramming in their respective combination. Both of these genes have been shown to be oncogenic meaning they pose risk of tumor development. (Cobellis & Romito, 2015; Kamath et al., 2023). Humans and planarians both share a tumor suppressor gene called LRIG1, and, considering planarians are not at similar risk,

this similarity makes this gene a target for regulation in iPSC to minimize risk of cancer onset while still allowing the use of the previously mentioned oncogenes (Chen, 2025). Looking further into the possible ways to make this gene more active in humans could be a vital tool in preventing complications from cell reprogramming and fighting cancer in general. Examining hiPSCs using neoblasts as a model due to planarians extraordinary regenerative abilities reveals new possibilities in the stem cell field that could not be uncovered using hESC or another model organism.

Conclusion

As a new, ever-growing field, there are challenges that come with induced pluripotent stem cells. These challenges range from difficulties in reprogramming the cells to challenges with the cells themselves due to their nature as not naturally occurring in the body. Looking at naturally occurring adult pluripotent stem cells that excel in regeneration like planarians' neoblasts can highlight avenues that are worth exploring to progress stem cell therapy.

The two main sets of genes involved in reprogramming are either Oct4, Sox2 Klf4, and Myc or Oct4, Sox2, Nanog, and Lin28. One issue that can arise from these gene combinations are the oncogenes Myc and Lin28's risk of causing tumors. As an example of how examining planarians can help with stem cell research for humans, planarians and humans both possess the tumor suppressant gene LRIG1 which makes this gene a possible solution to allow these oncogenes to remain present while combating any cancer risk they might pose. iPSC are a promising new avenue of regenerative medicine for humans and there's a lot more to discover and improve about them. Looking at iPSCs in comparison to planarians and neoblasts is significant since they are one of the few organisms with adult pluripotent stem cells and are able to regenerate nearly their entire body. Looking at differences and similarities between these pluripotent stem cells can help researchers understand what to improve in order to achieve regenerative abilities likened to those of planarians. Unfortunately being a relatively new technology it is difficult to determine whether many faults in iPSCs are due to their nature or are just flaws resulting from the reprogramming stage. It is also challenging to compare planarians' abilities to iPSCs since planarians' biology differs so greatly from that of humans'.

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Impact of Athletic and Artistic Ability on Personality

Sophie Yue Potvin

Abstract: Many students have an impressive range of extracurricular activities, such as art or sports, which make up a big part of their lives. However, there has not been much research conducted on how identifying as an artist or athlete can affect how adolescents view their personality. We analyzed how perceived sport or art ability can change adolescents' personality perception. Previous research shows how athleticism can lead to higher extroversion, while artistic ability may lead to openness to experience. Therefore, this study directly compares the two using a Likert scale survey to contrast the differences in how they affect personality. Using Pearson correlational analyses, it was found that artists tended to rate high in conscientiousness, while athletes rated high in extroversion and patience. This indicates that self-identified artists tend to see themselves as conscientious, while self-identified athletes tend to see themselves as patient and extroverted. This study confirms that self-perceived athletic/artistic ability correlates with personality perception, each associated with distinct characteristics.

Introduction

Can a simple childhood preference for art or sports lead to a distinction that impacts one's entire personality? Adolescents participate in athletics and/or the arts as extracurricular activities, which impact their friendships, talents, and day-to-day life. This can alter how they see the world and what kind of person they become. Thus, we will examine associations between domain-specific self-perceptions (sports/art ability) and self-perceived personality traits through a cross-sectional correlational survey. Self-perception is necessary to this study because it is shaped by experiences and social interactions and potentially could be affected by early exposure to arts and sports. While self-perception is not always the same as one's true personality, the two are closely connected and can influence each other. The survey was designed to test neuroticism, self-esteem, patience, agreeableness, openness, conscientiousness, and extroversion. These traits are significant because they make up a large part of a person's personality, and can give insight into their strengths and weaknesses as well as how they behave. It is essential for researchers to recognize why a person has these traits to understand their personality and character. Personality can impact one's life and decisions, as well as affect relationships and interactions with people. This study will focus on the importance of activities to self-perception of personality and specific ways they correlate.

Literature Review

Previous research on the personality of athletes suggests a strong correlation between sports participation and improved socialization (Tazegül, 2014). This might be caused by a variety of reasons, such as the large amount of communication between teammates, coaches, and rival athletes. In a study conducted on the influence of sports on previously untrained university students, it was found that sports had a positive effect on personal development and socialization. During the study, 50 university students practiced kickboxing for 2 hours a day, 4 days per week, for 3 months. At the end of the study, researchers measured personalities and found that the trait of neuroticism had decreased and extroversion had significantly increased. (Tazegül, 2014). This study suggests that students developed higher extroversion and lower neuroticism after participating in short-term sports training, meaning those who practiced sports for longer periods of time will also display those traits. Another recent study compared the personalities and creativity of over 500 university students who were and were not engaged in sports. They found using personality questionnaires that athletes showed higher extroversion and lower psychoticism compared with non-athletic students (Top & Mustafa, 2018). This reaffirms the previous research and verifies the idea of athletes being more extroverted and less neurotic, which will be tested in the present study.

The studies relating to art and personality have been more contradictory, and there is a need for more examination and research. One experiment performed was focused on personality as a predictor of art experience in university freshmen. It was found that openness to experience was a large predictor of art experience, and students who were very open were likely to be artists (Furnham & Chamorro-Premuzic, 2004). This indicates that artists will rank higher in openness to experience than others, and artistic experience would likely be a factor in that. Alternatively, a literature review of multiple art education studies found conflicting associations. The biggest improvements in students undergoing art education were found to be in conscientiousness and extroversion, not openness to experience. It was also found that arts education was more influential early on, meaning results might be different for older students. There were also some limitations to the evidence, as many studies were context-specific, had biases, and had differing results. The authors concluded that there needed to be more research and follow-ups for this study, and the results required more evidence (Grosz et al., 2021).

Self-perception tests are a simple and effective way to collect personality data, but these tests are not always accurate (Vazire et al., 2010). While people do have some self-knowledge, their perceptions are not always true to how they actually act. A comparison of self-assessments to observable behavior found that the two are only moderately similar. This is also found within comparisons using others' reports of one's personality. It was found that self-perceptions are not more accurate than those of close friends or family, and people do not always know themselves best (Vazire et al., 2010). This can impact the results of a personality survey, as how participants respond might not be the same as their behavior. It is important to note this before interpreting data from a survey, as it can give insight into responses and correlations.

With so much previous research, the importance of the present study might get lost in all of the related information. However, the information provided is relevant and different from previous studies. While previous studies focus on artist personality or athlete personality, the present study directly contrasts the two, which could help better understand the results. The focus on adolescents sets it apart from other studies with varying age ranges, giving a different perspective and data. This could also give more insight into patterns of adolescent personalities as a result of their activities and add more to research on youth personality perception. This study proposes that (1) Students who self-identify as athletes will perceive themselves as high in extroversion and low in neuroticism, and self-perceived artists will rate high in openness and conscientiousness. Additionally, we hypothesize (2) there is a correlation between perception of athletic/artistic ability and perception of personality.

Methods

The present study is based on a cross-sectional, correlational survey study on the associations between self-perceived artistic and athletic ability and personality self-perception. The data collected was solely quantitative, and the research conducted was non-experimental. The independent variable in this study is participants' self-perceived athleticism and artistic ability. The dependent variable is the resulting personality traits. The participants of this study were 84 self-identified high school girls, aged 14-18, in upstate New York. The recruitment was through convenience sampling, with classmates and peers volunteering to participate in the survey. The survey time for most students was about five minutes, and responses were collected in the span of 3 weeks. The survey was composed of 28 statements that relate to the following traits: neuroticism, self-confidence, patience, agreeableness, openness, conscientiousness, and extroversion. Participants rated each statement on a 1 (Strongly Disagree) to 5 (Strongly Agree) Likert scale based on how true it was for them. Additionally, participants were asked to rank their artistic and athletic abilities on the same scale. Some negatively worded statements were reverse-coded before averaging scores.

Cronbach's alpha was used to test the reliability of the scale for each trait, all of which ranked from acceptable to good, which supports the accuracy of the results. The overall trends of the responses were determined using standard deviation and calculating means. Pearson correlational analyses were used to examine the relationships between self-perceived athletic ability and personality traits, along with self-perceived artistic ability and personality traits. Linear regression was also used to see whether athleticism or artistic ability predicted unique personality traits. The students' perceived ability in each category was entered as a predictor, and personality traits were entered as outcome variables. The statistical analysis focused on whether artistic versus athletic students see their personalities differently, as well as the association with specific personality traits.

Results

The correlational analyses confirmed a statistically significant small to moderate positive correlation between athletes and extroversion ($p = 0.02$). Athletic ability also had a significant moderate positive correlation with patience, which was the highest correlation of all the tested traits ($p = 0.01$). Additionally, athletes tended to report low neuroticism, but this was not strong enough to be statistically significant. Similarly, athletes experienced a small to moderate but not significant correlation with openness. Athletes did not display any significant correlations with self-esteem, agreeableness, or conscientiousness. In comparison, artists displayed a small to moderate positive correlation with conscientiousness, which was statistically significant and confirms previous hypotheses and studies ($p = 0.02$). However, there was almost no correlation between artists and openness, which goes against the previous hypothesis. Artists also did not experience any significant correlations with the traits of self-esteem, patience, extroversion, agreeableness, and neuroticism.

Discussion

The results of the correlational survey show three significant connections between personality and activities, which proves that perceived athletic and artistic ability can impact perceived personality. Due to the survey's reliance on self-perception, the personality traits measured by each individual might not be accurate as to how they actually behave. However, this study highlights how identifying as an athlete or artist can affect the way you see yourself, which is equally important and influences how you act. The results show a positive correlation between athleticism and extroversion, which suggests that someone who considers themselves athletic will also often consider themselves extroverted. This corresponds with previous studies that compare athletes to non-athletic students (Top & Mustafa, 2018), supporting the current data of athletes having high extroversion. These two characteristics may be associated due to athletes working in teams and needing to communicate with each other to perform well. There was also a positive correlation between artistic ability and conscientiousness, meaning self-perceived artists tend to think of themselves as more conscientious or organized. This aligns with studies on the effects of arts education, where students displayed higher conscientiousness, despite the participants being primarily younger students. This correlation may exist due to the intense concentration and organization needed to perfect details in an art piece or performance. However, openness, which was previously expressed as a strong predictor of artistic ability, had little to no correlation with high artistic perception in the results of this study. Notably, there was also a strong connection between self-perceived patience and athleticism, where athletes tended to consider themselves more patient. This was not represented in any previously mentioned studies; however, it could result from the frequent and repetitive practice of drills and techniques until an athlete masters a skill.

The participants for this survey were self-identified adolescent girls ages 14-18, which potentially influenced results, explaining why some data points differed from experiments that primarily focused on adults. Personality often shifts from teenage to adult years as one grows and develops, and age might influence how participants respond, as some traits appear or change once someone gets older. Additionally, a majority of the participants attended the same private Catholic school, meaning the responses were not random, and participants could interact and influence each other's personalities. Some participants might act similarly to try to fit in, or friends might behave alike simply from spending so much time together. The participants were also all identified as women, which describes the effects of socialization and subsequently impacts results through normative perception experiences. This might limit or change the variety in participant responses.

There is still a lot of potential for research using information gained in this study. Self-perceived artists and athletes tended to be two separate groups, with very few students identifying as both, which could lead to examining the lack of overlap and what causes athletes and artists to be so different. Future research could also confirm why athletic or artistic ability corresponds with a specific trait using a qualitative survey and comparing participant responses, or by analyzing how each activity affects the development of personality. Self-esteem, openness, agreeableness, and neuroticism were not present within correlation analyses in the results from this survey, so future studies could examine these traits specifically to see what other factors they are related to. This study provides insight into adolescents' self-perception of athletic and artistic ability and its correlation with specific self-identified personality traits, which contributes to further research regarding the implications of personality development.

Table 1

Correlation Between Personality Traits and Athletic vs. Artistic Ability

Trait	r value Athlete	p-value Athlete	r value Artist	p-value Artist
Self Esteem	0.13	0.25	-0.03	0.79
Patience	0.30	0.01	-0.12	0.30
Extroversion	0.26	0.01	-0.18	0.10
Agreeableness	0.009	0.41	-0.09	0.44
Conscientiousness	-0.09	0.42	0.25	0.02
Neuroticism	-0.16	0.15	-0.14	0.22
Openness	-0.21	0.06	-0.09	0.45

Note. *p*-value has been rounded to the second decimal for visual purposes.

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The Creation and Sustenance of Liquid Water on Exomoons

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Abstract: Exomoons are theorized to be quite common in the universe, and as such have the potential to sustain liquid water. They can acquire heat from a variety of sources to form water and keep it in liquid form, allowing the moon to be potentially habitable for life. Models suggest that this is possible, and even probable due to the large numbers of theorized exomoons. While none have been conclusively discovered to date, advancing technology should allow us to uncover these satellites in the near future. In this review, we will explore the potential sources of heat and detection methods for exomoons, the necessary chemistry and conditions required to form and sustain liquid water, as well as potential observational directions in the future for chemical analysis. Finer instruments could detect the smaller influences of exomoons and determine their conditions, the most important of which being their access to heat and atmospheric composition. Water vapor combined with an Earthlike atmosphere would be a strong indication of water, and complex organic compounds or waste in the atmosphere would be a possible indication of life.

Keywords: exomoons, transit spectroscopy, biosignatures, habitability

Liquid water is absolutely necessary for sustaining life (Pohorille 2018). In recent years, we have discovered that it can exist on small, cold moons that exist in environments much more hostile than Earth. This is demonstrated in our own solar system by moons such as Enceladus and Europa (Lunine 2017), and it stands to reason that this can occur in other solar systems as well. Exomoons may offer a much wider range of potentially habitable bodies than planets do. However, while we have confirmed the existence of over 6000 exoplanets (Tran 2023), we have yet to conclusively discover an exomoon. As such, all study of these mysterious objects is dependent on theory and mathematical models only.

Despite the lack of confirmed detections, the models predict that water could exist on exomoons in a variety of scenarios (Ávila et al. 2021), greatly assisting in humanity's search for life across the stars. While exomoons are theoretically capable of holding water in conditions harsher than Earth's, there are still a variety of factors necessary to ensure its survival. In this review, we will discuss the necessity of heat and heat sources, the qualities of the moon and its planet, the chemistry involved in the formation of water and its retention, and how we might potentially detect a habitable exomoon.

I. Heat Sources and Retention

A critical component for the formation of water and keeping it in liquid form is sufficient heat. This can come from a variety of sources, including the host star, tidal forces, atmosphere, geologic activity, and even background radiation. First, and likely the most common source of heat for habitable exomoons, is the energy from the host star of the planet-moon system coupled with a heat-regulating atmosphere. This is very similar to how Earth operates, but the atmosphere would be even more critical for the moon. It would sometimes be entirely in the shadow of its planet and possibly have areas facing away from the star for longer periods of time than on Earth. Without an atmosphere to trap the heat, the moon would experience radical temperature swings similar to those experienced by our own Moon and the planet Mercury, which can rise to 121°C and 427°C during the day and fall to -133°C and -180°C at night, respectively (Barry 2023; Cermak 2017). The presence of a thick atmosphere is absolutely necessary to retain heat

from the host star and protect the water from receiving too much radiation. If it received the full force of the solar wind, the water would evaporate and be blasted off into space, similar to what likely happened to the planet Mars (Jakosky 2021). This necessitates the presence of sufficient mass to hold in the atmosphere and a strong magnetic field (either the moon's or the planet's) to deflect harmful radiation. Exomoons do not need as much atmospheric mass to retain heat over their area as a planet does, meaning it may be easier to acquire a sufficiently thick atmosphere. Alternatively, a layer of ice on the surface of the moon could shield liquid water beneath from both radiation and drastic cooling, providing there was sufficient warmth present from the interior of the moon. This is believed to be the scenario on Europa and Enceladus, some of the most promising sources for liquid water beyond Earth (Lunine 2017). Although, this water would be subsurface, meaning conditions inside it would be radically different from Earth.

The size, mass, and orbit of the host planet and moon are also critical for the maintenance of heat on the moon. If the moon spends long periods of time in the planet's shadow, then the water could freeze due to heat loss. To mitigate this, the moon must be of sufficient mass to hold on to an atmosphere that traps the heat and regulates it. The planet, as such, must also be of sufficient mass to stably retain a moon of that size while remaining small enough so as not to put the moon into long periods of shadow. Furthermore, if the moon is tidally locked to its host planet, it will have incredibly long day-night cycles. Our moon is tidally locked to Earth, and its daylight cycle lasts almost a month. This leads to extreme temperature variations and would make it extremely difficult even for a moon with a thick atmosphere to retain heat during the night and not overheat during the day.

The moon does need to rotate separately from the planet and revolve at a sufficient velocity around the planet in order to generate tidal forces that cause its core to spin. This creates a magnetic field around the moon and causes volcanic activity that could lead to the energy required to form water in the atmosphere (Green et al. 2021). The addition of heat to the moon caused by tidal forces could be significant even without the presence of a host star and could possibly be a critical source of energy to form water on exomoons around free-floating planets. Because free-floating planets are believed to make up the majority of worlds in the universe (Sumi et al. 2011), they likely also present a large sample of exomoons. However, due to the absence of energy input from a star, the formation of water on these bodies necessitates other sources. Recent models (Ávila et al. 2021) predict that tidal forces, coupled with background radiation from other bodies in the universe, could provide enough energy to create and sustain liquid water in specific scenarios. As such, these sunless moons cannot be ruled out in the search for liquid water.

II. Chemistry Involved in Creation and Sustenance of Water

After enough heat energy is added to the atmosphere of an exomoon, the atmosphere must then have the right composition in order to form liquid water. Fortunately, the elements necessary to form water are relatively common in the universe, although life demands many additional compounds and conditions. Using Earth as an example, we can look for oxygen gas, water vapor, carbon, and nitrogen as potential indicators of habitability. Additionally, greenhouse gases such as carbon dioxide might indicate heat retention on the exomoon. All of these gases in the atmosphere together probably point to a stable environment for liquid water and carbon-based life, as on Earth. However, the distribution of these molecules must be balanced in order to mitigate runaway chemical reactions and to allow for a stable environment for life to exist.

A potential major indicator of life would be chemicals in the atmosphere that, as far as we know, are primarily produced by living organisms. Some such biosignatures are methane and ammonia, commonly produced through organic decomposition (Kelly 2025). However, they are also common on many other worlds that likely do not have life, such as Uranus and Neptune (Lunine 1993). More complex organic compounds, however, coupled with a presence of methane or ammonia in an atmosphere composed of the chemicals mentioned above likely implies habitability and can strongly indicate the presence of life. To this end, the most accepted way of discovering the contents of a world's atmosphere is through transit spectroscopy, which utilizes the comparison between the spectra of a body and its host star to determine the chemicals present in the atmosphere of the body when it transits in front of its host star. The star's emission spectrum is then subtracted from the combined spectrum to reveal the composition of the body's atmosphere.

However, this has never been conducted at as fine a level as an exomoon. Until instrumentation becomes more precise, an exomoon having this type of atmosphere is unconfirmed yet remains theoretically possible.

III. Observation Techniques

There are, however, no confirmed detections of exomoons to date. Using the example of the number of moons in our own Solar System, as well as our current models of planetary formation, exomoons should be quite common (Barr 2016). This leads us to believe that our current detection methods are simply not precise enough to register the small mass of an exomoon. They could be directly imaged with a highly detailed camera, detected by observing the radial velocity of a planet we can directly observe, or detected through smaller dips in a star's light using the transit method. The latter seems the most promising, as it is the method that requires the least updating to our telescopes and has been proven to work with most of the exoplanets discovered to date (Balzer 2021). It is theoretically possible that an exomoon could be discovered using this method if it was orbiting its planet at the right inclination. There have even been some potential discoveries of exomoons using this method (Espinoza 2018a), but they are unconfirmed.

(Espinoza, Luis. "Transit of Kepler-1625b and Suspected Moon." *NASA Science*, NASA, 3 Oct. 2018, http://science.nasa.gov/asset/hubble/transit-of-kepler-1625b-and-suspected-moon/.)

Once transit discoveries are confirmed, we can use spectroscopy to observe the contents of the exomoons' atmospheres and determine if they might be suitable for containing water or hosting life, as mentioned in the previous discussion of biosignatures and in Figure (1). If an exomoon was discovered by direct imaging or radial velocity, however, its composition would be very difficult to confirm. Direct imaging might yield results from the world's emission spectrum but would require precision instruments on a scale we do not currently possess. However, present data might be sufficient to confirm some exomoons via the transit method from telescopes such as Kepler, James Webb, and TESS. In the future, the Habitable Worlds Observatory will greatly enhance our ability to detect exomoons that could possibly have liquid water (Cowan et al. 2025).

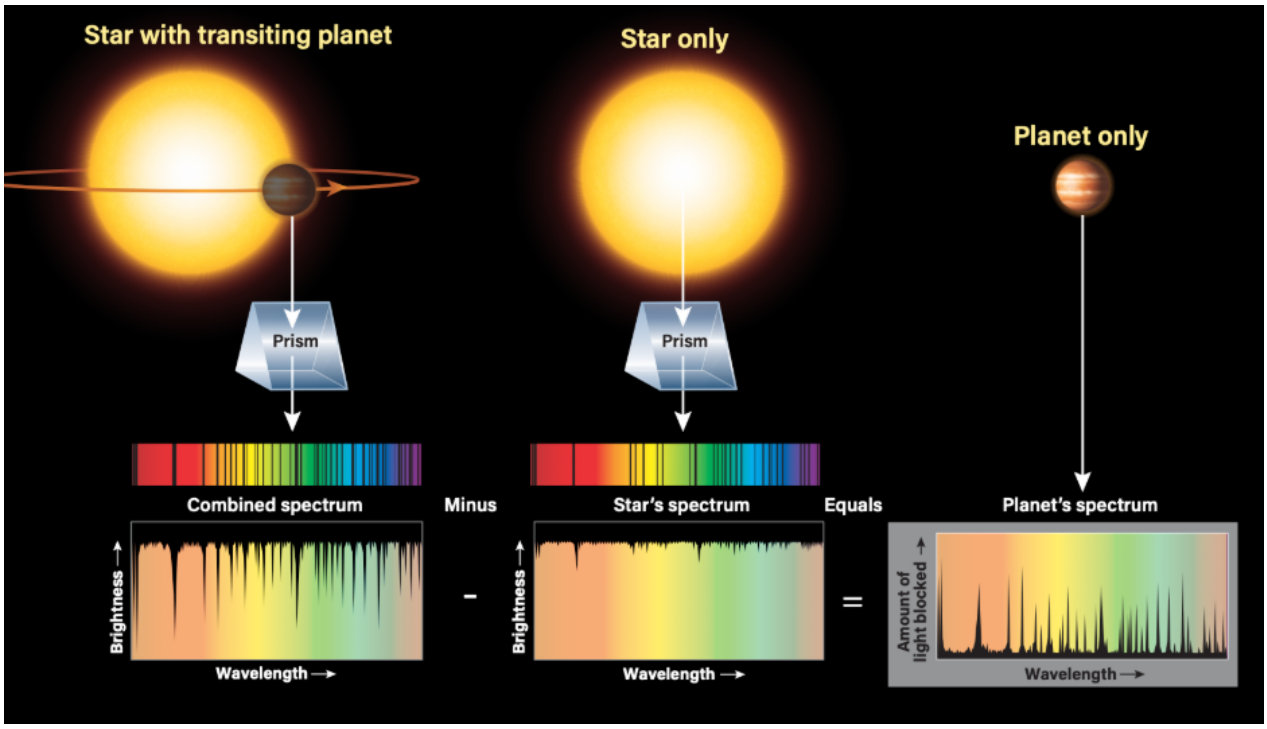

Figure 1. Transit spectroscopy involves taking the chemical spectrum of a star with a transiting planet and subtracting the star's spectrum to find the absorption spectrum of the planet. That is then used to determine the composition of the planet's atmosphere. This can be observed when a known planet passes in front of its star, and would in theory apply to exomoons as well. Figure from: "The Search for Biosignatures in the Milky Way", by R. Kelly (2025), *Astronomy.com* (http://www.astronomy.com/science/the-search-for-biosignatures-in-the-milky-way/).

IV. Discussion and Conclusion

Despite current limitations, exomoons are one of the most likely candidates for habitability and the sustenance of liquid water. While they do need Earthlike conditions, they likely have a much higher possibility of them due to the sheer volume of their predicted numbers. However, all information on them at present is dependent on models and comparison to moons in our own solar system, which has proven to be a uniquely finely tuned system in the universe. Because there have been no confirmed detections of exomoons to date, severe limitations are placed on the depth or our knowledge of the subject, and we must allow for a very wide range of possibilities.

Exomoons can acquire sufficient heat to create and sustain water from a variety of sources, including starlight, tidal forces, and background radiation. This heat keeps the water in liquid form as well as initiates chemical reactions that form both water and an environment suitable for it. These chemicals are detectable from long distances using transit spectroscopy, although at a level of precision never attained before. Nevertheless, as technology advances, looking for such chemical signatures from a moon believed to have sufficient heat will be a very promising way to uncover exomoon candidates for habitability.

Advancing technology will allow us to detect finer, more precise dips in light from transiting exomoons that will greatly expand the scope of our knowledge. Additionally, a better understanding of liquid water candidate moons in our solar system, such as Europa and Enceladus, will help us improve our models and help us know what to look for in an exomoon. Upcoming missions such as Europa Clipper will assist in gathering more data to this end (Barnett 2025), while the Nancy Grace Roman Telescope will likely uncover many more worlds through transit and microlensing (Balzer 2021). Improved detection technology as well as improved models are probably the most helpful fronts for the search for water on exomoons.

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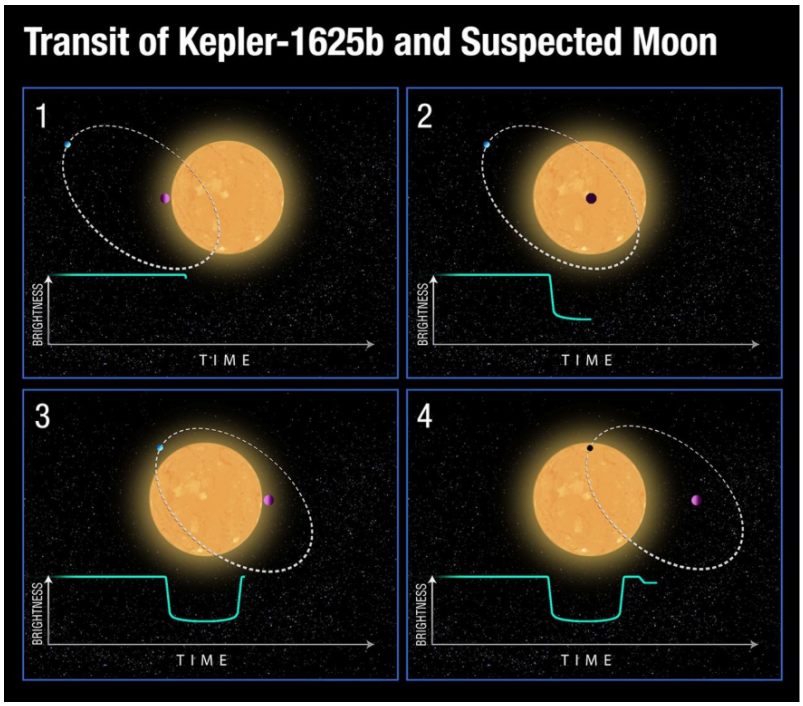

Figure 2. An exomoon could potentially be discovered by observing a smaller, secondary dimming event as a planet transits its star. Shown above is one such event with the planet Kepler-1625b that possibly demonstrates the existence of an exomoon.

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