

International journal of
crisis & safety

Vol. 10 No. 0

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Publisher: J-INSTITUTE
ISSN: 2189-7603

Website: j-institute.org

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DOI Address:
dx.doi.org/10.22471/crisis.2025.10.0.01



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The Impacts of Cyberbullying Victimization on Academic Helplessness in Elementary School Students: Mediating Effects of Attention Problems

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Abstract

Purpose: The core objective of the current study was to assess how cyberbullying victimization influences academic helplessness in elementary students, specifically focusing on the mediating role of attention problems.

Method: This study involved 338 students from grades 4 to 6 in elementary schools located in the Seoul metropolitan area. The participants were surveyed on levels of cyberbullying victimization, attention problems, and academic helplessness. Data analysis was conducted via descriptive statistics and correlation analysis, followed by Structural Equation Modeling (SEM).

Results: The results of the analysis were as follows. Firstly, cyberbullying victimization in elementary school students was found to significantly increase both attention problems and academic helplessness. Secondly, attention problems were found to significantly increase academic helplessness. Thirdly, attention problems were found to mediate the relationship between cyberbullying victimization and academic helplessness. Specifically, the following sequential pathway was identified as significant: 'cyberbullying victimization → attention problems → academic helplessness'.

Conclusion: These findings suggest that the harm of cyberbullying extends to cognitive and academic domains, beyond emotional distress. The study provides new insights for developing effective support systems that address not only the emotional aftermath but also the cognitive and academic difficulties faced by cyberbullying victims.

Keywords: Cyberbullying Victimization, Academic Helplessness, Attention Problems, Elementary School Students, Insight

1. Introduction

It is widely agreed that school violence is an extremely serious issue that must be eradicated from the Korean educational setting. The problem of school violence has long been an intractable, chronic issue in Korean society, evidenced by a recent popular drama on an online video platform, the main theme of which was 'a school violence victim's revenge.' According to the Ministry of Education's '2025 First School Violence Victim Survey,' the percentage of students who reported experiencing school violence reached an all-time high of 2.5% [1]. Of particular note is the decreasing age of school violence victims. Among elementary, middle, and high school students, school violence victimization among elementary school students was analyzed to be particularly severe. The rate of school violence victimization for elementary students was 5%, double the overall victimization rate, which marks a 19% increase compared to the previous year. These results undermine the efforts of the Ministry of Education and local education offices, which have implemented various policies to prevent school violence.

In addition to the quantitative increase in school violence, a noteworthy aspect is the change in the forms of school violence. Among the types of school violence, cyberbullying, mediated by

the internet and smartphones, is rapidly increasing. In fact, the 2025 School Violence Survey showed that while other types of school violence remained similar or decreased compared to the previous year, cyberbullying increased by 5.4%. According to the 2024 Cyberbullying Survey by the Korea Communications Commission and the Korea National Information Society Agency, 42.8% of Korean adolescents have experienced cyberbullying[2]. Particularly concerning is the sharp rise in severe types of cyberbullying that can be linked to crimes such as cyberstalking.

Cyberbullying possesses dangerous characteristics that clearly distinguish it from traditional school violence. First is anonymity and non-face-to-face nature. Since perpetrators can attack others without exposing their identity online, random acts of cyberbullying occur frequently. Indeed, the 2024 Cyberbullying Survey found that about half of all victimization experiences stemmed from completely unknown assailants. Second is the non-face-to-face nature, which implies the lack of spatial constraints in cyberbullying. While traditional school violence occurs face-to-face within specific physical spaces, cyberbullying occurs non-face-to-face without spatial limitations. Consequently, while traditional school violence can be temporarily halted by simply leaving a specific location (e.g., school, classroom), cyberbullying can occur anywhere in virtual space. Third is perpetuity and continuity, meaning cyberbullying has no temporal constraints. Cyberbullying victimization can occur at any time, 24 hours a day. Particularly, the development of the Internet and smartphones has completely eliminated temporal and spatial restrictions on cyberbullying. Due to these characteristics of cyberbullying, victims often lack a temporal and spatial safe zone to escape the violence.

When cyberbullying persists due to these characteristics, the harm can be far more severe than that of offline school violence. The harms that cyberbullying inflicts on adolescents are extensive. Firstly, cyberbullying victimization is reported to be a core factor causing severe psychopathology in adolescents[3]. Cyberbullying victims exhibited significantly higher levels of depression and anxiety compared to general students. When these levels of depression and anxiety become severe, victims may experience extreme helplessness, and in more severe cases, their likelihood of making extreme choices such as suicidal ideation or suicide attempts increases. Secondly, cyberbullying victimization is reported to negatively affect adolescents' physical health[4][5]. Cyberbullying has been shown to cause digestive issues, such as stomachaches, and sleep disorders, such as insomnia. Especially, prolonged cyberbullying victimization is reported to exacerbate physical health problems like headaches and sleep disorders. Next, cyberbullying victimization is reported to severely impair the formation and maintenance of peer relationships for victims[6]. Cyberbullying victims show increased distrust and fear of others, similar to social anxiety[7]. The fear and distrust of others formed through cyberbullying naturally negatively impact the formation and maintenance of peer relationships, making the establishment of healthy friendships difficult.

Recently, problems related to academic performance among the harms of cyberbullying on adolescents' lives have drawn attention[8]. Cyberbullying not only harms the mental, physical health, and social relationships of adolescent victims but also negatively affects their overall academic performance. In fact, preceding studies report that experiencing cyberbullying victimization negatively affects academic achievement[9][10]. Specifically, this negative impact can be amplified for students already experiencing academic difficulties, such as those with high academic stress. Given the current situation where adolescents' cyberbullying victimization is rapidly increasing, minimizing the harm cyberbullying inflicts on their lives is extremely crucial. To minimize the harms of cyberbullying, it is vital to first understand the specific structure—the processes and pathways—through which cyberbullying affects adolescents' lives.

Firstly, this study selected academic helplessness as a variable through which cyberbullying victimization negatively influences the lives of adolescents. Academic helplessness refers to a state of psychological exhaustion where a student loses control over their academics and gives up on academic attempts and effort due to experiencing repeated academic failure. Chronic

cyberbullying, due to its lack of spatial and temporal constraints, can lead to continuous victimization. This constant experience of victimization can lead to a loss of control, or learned helplessness, over the cyberbullying situation—a sense that they can do nothing about it[11]. This loss of control over the cyberbullying situation aligns with academic helplessness, which is characterized by a loss of control over academic situations. In other words, the learned helplessness formed through experiencing cyberbullying victimization is highly likely to be directly transferred to academic situations or to amplify already established academic helplessness. Indeed, the results of several preceding studies, which demonstrate that cyberbullying negatively impacts victims' academic achievement in school life and can increase learned helplessness, support this assertion[12][13].

Next, this study set attention problems as a mediating variable between cyberbullying victimization and academic helplessness. In fact, the latest research indicates that bullying can negatively affect victims' cognitive function beyond simple psychological and emotional harm[14]. In fact, several studies demonstrate a high correlation between violence victimization and cognitive function including attention[15][16][17]. Attention is closely linked to academic performance, and attention problems are reported as a key factor causing academic helplessness[18][19][20]. Note that while attention is highly correlated with learning problems, research connecting cyberbullying victimization to attention remains insufficient. Furthermore, it is difficult to find studies that analyze the mediating effect of attention problem on the relationship between cyberbullying victimization and academic problems, such as academic helplessness. Accordingly, this study aims to confirm the impact of cyberbullying victimization on academic helplessness and to examine the mediating effect of attention problems in this process. Specifically, this research will be guided by the following two research questions:

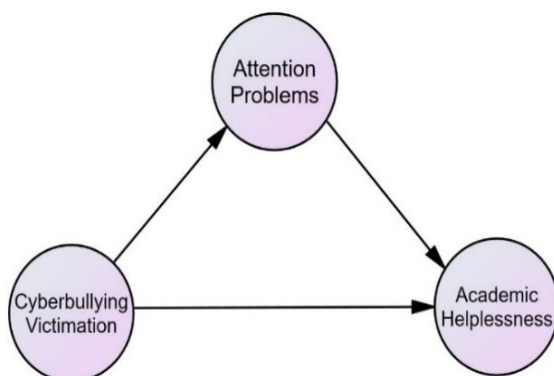
1. How does cyberbullying victimization affect academic helplessness?
2. Does attention problem mediate the relationship between cyberbullying victimization and academic helplessness?

2. Research Method

2.1. Hypothetical model

This study established a structural model in which cyberbullying victimization has a direct impact on academic helplessness while also exerting an indirect influence through the mediation of attention problems. The specific research model is presented in <Figure 1>.

Figure 1. Hypothetical model.



2.2. Research subject

Participants included 338 pupils from the 4th to 6th grades, recruited from two elementary schools in the capital area. First, the researcher contacted the schools selected via convenience sampling to gauge their willingness to participate. Questionnaires were then sorted according to the number of students in grades 4–6 at the consenting schools and delivered via mail. The distributed questionnaires were collectively provided to the homeroom teachers of the 4th to 6th grades at the participating schools. The survey was conducted by the homeroom teachers in their respective classes, after which the completed questionnaires were collected. The homeroom teachers then returned the collected questionnaires to the researcher via mail. Of the 349 questionnaires initially returned, 11 were excluded from the analysis due to insincere responses or missing data (e.g., all responses marked with the same number, or personal information or entire scales not properly completed), leaving 338 copies for final analysis. The basic characteristics of the student participants (gender, grade level) are presented in <Table 1>.

Table 1. Characteristics of the participants.

| Characteristic | Classification | Frequency(N) | Ratio(%) |
|----------------|----------------|--------------|----------|
| Gender | Male | 192 | 56.8 |
| | Female | 146 | 43.2 |
| Grade year | 4 | 97 | 28.7 |
| | 5 | 126 | 37.3 |
| | 6 | 114 | 33.7 |
| | Non-response | 1 | .3 |

2.3. Measurement tools

The instruments used to measure the participants' levels of cyberbullying victimization, attention problems, and academic helplessness in this study are as follows.

2.3.1. Cyberbullying victimization

To measure the level of cyberbullying victimization, this study utilized the Cyberbullying Victimization Scale originally developed by Campfield and translated/adapted by Choi[21][22]. This scale is composed of five items. A higher total score indicates a greater experience of cyberbullying victimization. The scale demonstrated satisfactory internal consistency ($\alpha = .857$).

2.3.2. Attention problem

For measuring participants' attention problems, this study employed the attention problem subscale from the Inattention, Hyperactivity, and Impulsivity Scale developed by Choi[23]. This scale consists of a total of nine items and is rated using a 4-point Likert scale. A higher total score indicates more severe attention problems. The scale demonstrated satisfactory internal consistency ($\alpha = .817$).

2.3.3. Academic helplessness

To measure the participants' academic helplessness, this study utilized the Academic Helplessness items from the Korean Child and Youth Panel Survey. This scale is composed of a total of 12 items. A higher total score signifies a more severe level of academic helplessness. The scale demonstrated satisfactory internal consistency ($\alpha = .913$).

2.4. Data analysis

Data analysis was conducted via descriptive statistics and correlation analysis, followed by Structural Equation Modeling (SEM). First, descriptive and correlation analyses were performed to examine the normality of the observed variables and to check for potential issues with the assumption of multicollinearity. Second, model fit analysis was conducted to verify whether the hypothesized research model was acceptable. Third, path analysis was employed to confirm the relationships and influences among the variables in the research model. Finally, to test the mediating effect of attention problems on the relationship between cyberbullying victimization and academic helplessness, bootstrapping was utilized after setting up a phantom variable.

3. Research Results

3.1. Correlation and normality check

First, correlation analysis was performed to verify whether the measured variables presented any issues with multicollinearity. As shown in <Table 2>, a positive relationship was observed among all measured variables, and the absolute values of the correlation coefficients ranged from .139 to .653, indicating that there were no significant issues with multicollinearity. Next, descriptive analysis was conducted to examine potential violations of the normality assumption for the measured variables. The results revealed that the skewness and kurtosis values for the cyberbullying victimization variable exceeded the acceptable thresholds. This is likely due to the tendency for specific students to be repeatedly victimized, which leads to a skewed distribution of the data. Accordingly, in the subsequent structural equation modeling analysis, the cyberbullying victimization variable was log-transformed to mitigate the impact of non-normality.

Table 2. Descriptive statistics and correlations of the measurement variables.

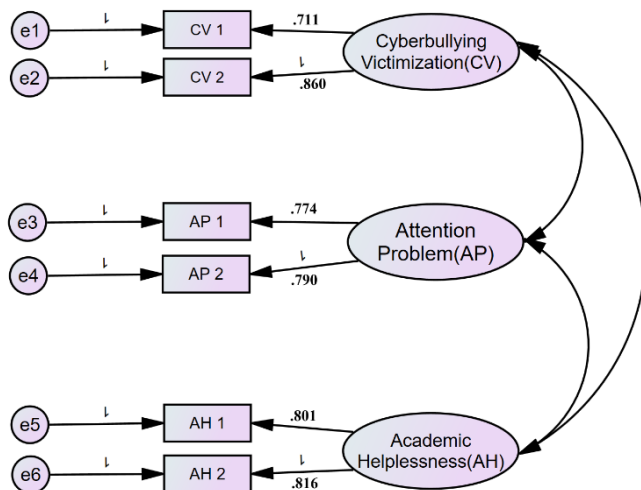
| | Cyberbullying victimization1 | Cyberbullying victimization2 | Attention problem1 | Attention problem2 | Academic helplessness1 | Academic helplessness2 |
|------------------------------|------------------------------|------------------------------|--------------------|--------------------|------------------------|------------------------|
| Cyberbullying victimization2 | .611** | | | | | |
| Attention problem1 | .160** | .174** | | | | |
| Attention problem2 | .231** | .139* | .611** | | | |
| Academic helplessness2 | .198** | .183** | .566** | .569** | | |
| Academic helplessness1 | .325** | .249** | .546** | .515** | .653** | |
| M | 1.619 | 1.220 | 1.955 | 2.187 | 2.035 | 1.679 |
| SD | .845 | .552 | .617 | .630 | .773 | .648 |
| Skewness | 1.459 | 3.113 | .465 | .035 | .513 | 1.025 |
| Kurtosis | 1.257 | 9.964 | .242 | -.497 | -.340 | .690 |

Note: *p < .05, **p < .01.

3.2. Measurement model analysis

Confirmatory Factor Analysis (CFA) was performed to assess the construct validity of the measurement model. The fit indices confirmed a satisfactory model fit with all values meeting the recommended thresholds (GFI=.983, TLI=.957, CFI=.983, RMSEA=.079). Additionally, as shown in Figure 2, all factor loadings were statistically significant ($p < .01$), ranging from .711 to .860. These findings demonstrate the validity of the scales and measurement variables used to represent the latent variables in this study.

Figure 2. Confirmatory factor analysis of measurement model.



3.3. Model fit analysis

Model fit analysis was conducted to verify the acceptability of the hypothesized research model in this study. The results, presented in <Table 6>, indicated $\chi^2(6)=18.637$, $p < .05$. Since the χ^2 statistic is known to be sensitive to sample size, other fit indices were examined. The absolute fit indices (GFI $> .9$, RMSEA $< .10$), comparative fit index (CFI $> .9$), and incremental fit index (TLI $> .9$) all met the conventional criteria for model adoption. Therefore, the hypothesized structural model was deemed to have an appropriate fit for the data.

Table 3. Model fit indices.

| Research model | χ^2 | df | p | GFI | CFI | TLI | RMSEA |
|----------------|----------|----|------|------|------|------|-------|
| | 18.637 | 6 | .005 | .983 | .983 | .957 | .079 |

3.4. Path analysis

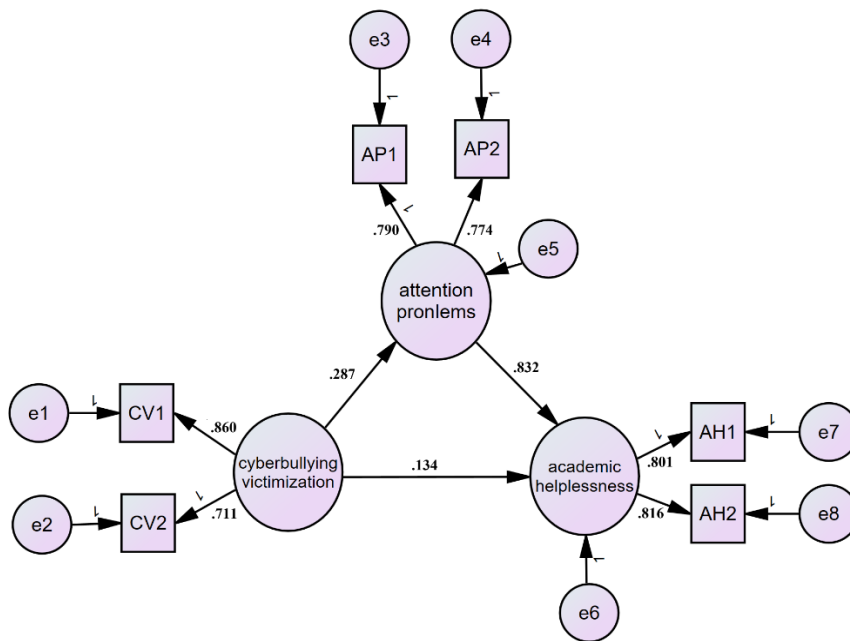
Path analysis was conducted among the latent variables in the research model to determine which path relationships among cyberbullying victimization, attention problems, and academic helplessness were statistically significant. As presented in <Table 4>, all paths established in the hypothesized research model were found to be significant. Specifically, the paths: Cyberbullying Victimization \rightarrow Attention Problems, Cyberbullying Victimization \rightarrow Academic Helplessness, and Attention Problems \rightarrow Academic Helplessness were all statistically significant. This indicates that as elementary school students experience more cyberbullying victimization, their attention problems and academic helplessness increase, and an increase in attention problems, in turn, leads to an increase in academic helplessness. The specific path coefficients between the latent and observed variables in the research model are presented in <Figure 3>.

Table 4. Analysis of path coefficients between variables.

| Pathway | Non-standardized coefficient | Standardized coefficient | Standard error | t |
|---|------------------------------|--------------------------|----------------|-----------|
| Cyberbullying victimization → Attention problems | .192 | .287 | .053 | 3.610*** |
| Cyberbullying victimization → Academic helplessness | .885 | .832 | .082 | 10.758*** |
| Attention problems → Academic helplessness | .095 | .134 | .042 | 2.271* |

Note: ***p < .001.

Figure 3. Standardized regression weight between the variables.



3.4. Analysis of mediating effects

Since the analysis revealed that cyberbullying victimization increased academic helplessness both directly and indirectly, the mediating effect was tested via bootstrapping after setting up a phantom variable on the mediating path to confirm the specific process by which cyberbullying victimization increases academic helplessness. The analysis results, as shown in <Table 5>, indicated that the mediating path was statistically significant at the 95% confidence level. Specifically, the sequential path leading from Cyberbullying Victimization → Attention Problems → Academic Helplessness was found to be significant. This suggests that cyberbullying victimization exacerbates attention problems, and these increased attention problems, in turn, further worsen academic helplessness.

Table 5. Mediating effects between variables.

| Pathway | Estimate | SD | p | 95% Confidence interval (Lower bounds, Upper bounds) |
|--|----------|------|------|---|
| Cyberbullying victimization → Attention problems → Academic helplessness | .170 | .054 | .003 | (.102, .290) |

4. Discussion

4.1. The impact of cyberbullying victimization on academic helplessness

The analysis results indicate that cyberbullying victimization significantly increases academic helplessness among elementary school students. This finding aligns with the results of numerous prior studies that analyzed the relationship between adolescent cyberbullying victimization and academic outcomes. The mechanism through which cyberbullying victimization increases academic helplessness in elementary school students can be explained as follows:

First, it is possible that emotional problems intensified by cyberbullying victimization increased academic helplessness. Cyberbullying victimization is reported to induce severe levels of depression and anxiety in students. Students who experience such severe depression and anxiety are likely to expend most of their cognitive and motivational energy on detecting and responding to external threats, such as school violence. This depletes the energy that should be allocated to school life and academics. When the energy to invest in academics is depleted, students naturally face an increased likelihood of experiencing failure in the academic performance process. Particularly, because cyberbullying, unlike offline school violence, allows for continuous harassment without spatial or temporal constraints, it is highly likely to induce chronic depression and anxiety. When experiencing such chronic emotional states, students may simultaneously experience feelings of helplessness and loss of control, believing they cannot escape the current situation. This cyclical connection between repeated academic failure, helplessness, and loss of control can readily lead to academic helplessness. The previous study which shows that cyberbullying victimization causes depression and consequently influences school dropout, supports this inference [24].

Second, there is a possibility that cyberbullying victimization increases academic helplessness by causing problems in school social relationships. Cyberbullying victimization is reported to negatively affect students' overall school lives, particularly by causing issues in their social relationships. Specifically, cyberbullying victimization has been shown to cause social withdrawal and social anxiety, while also increasing aggression. This social anxiety, withdrawal, and aggression caused by cyberbullying victimization can subsequently worsen peer relationships within the school. Peer relationships during adolescence form the core foundation for sustaining academic engagement and overall school life. If this core foundation collapses due to cyberbullying victimization, the victimized student may lose interest and motivation for school life and academics, which is likely to lead to helplessness regarding their studies and school participation. The previous study, which shows that adolescent cyberbullying victimization negatively affects school adjustment, mediated by aggression, supports this inference [25].

Third, it is possible that cyberbullying victimization interacts with pre-existing academic stress to induce academic helplessness. Academic stress is a crucial factor contributing to academic helplessness. A series of previous studies consistently report a positive correlation between cyberbullying victimization and academic stress [26][27]. These findings suggest that students already experiencing academic stress may be more vulnerable to cyberbullying victimization, or that the experience of cyberbullying victimization may further aggravate existing academic stress levels. Students already experiencing emotional exhaustion due to high levels of academic stress have little psychological energy left to cope with cyberbullying victimization, thereby increasing the likelihood of complete psychological energy depletion. This depletion eventually leads the student to lose control over the overall academic environment, likely plunging them into a state of academic helplessness, characterized by the abandonment of further effort.

4.2. The mediating effect of attention problems in the relationship between cyberbullying victimization and academic helplessness

The results confirm that attention problems significantly mediate the relationship between cyberbullying victimization and academic helplessness. This finding aligns with previous studies suggesting that cyberbullying victimization precipitates attention problems, which in turn exacerbate academic failure. Beyond simply confirming correlations, this study empirically verifies the structural pathways among these variables. The potential mechanisms underlying this mediation effect can be explained as follows: First, attention problems are likely attributed to the sustained activation of threat detection mechanisms triggered by cyberbullying. Unlike traditional bullying, cyberbullying transcends spatiotemporal boundaries, presenting an omnipresent threat. Consequently, victims are compelled to maintain a state of chronic hypervigilance to anticipate potential attacks. This constant diversion of cognitive resources toward monitoring threats inevitably depletes the attention required for academic tasks, thereby heightening the risk of academic helplessness.

Second, emotional distress, specifically depression and anxiety, impairs executive functions necessary for regulating attention. As noted in prior research, cyberbullying significantly elevates anxiety levels[28][29]. Chronic anxiety maintains excessive physiological arousal, which disrupts executive functions—the higher-order cognitive processes responsible for sustaining attention and inhibiting distractions[30][31]. Consequently, this emotional dysregulation degrades executive control, directly leading to attention problems and subsequent academic helplessness[32][33]. Third, somatic symptoms and sleep disturbances resulting from chronic stress negatively impact cognitive capacity. Victims frequently report physical ailments such as headaches and stomachaches, alongside sleep disorders like insomnia. These persistent physiological issues compromise the brain's restorative processes, making it difficult to maintain attention during class. As supported by review studies[34], sleep deprivation and somatic complaints directly diminish cognitive functions, thereby mediating the link between cyberbullying victimization and academic helplessness.

4.3. Limitations and recommendations for further study

Although this study provides meaningful insights into the structural relationship between cyberbullying victimization, attention problems, and academic helplessness, several limitations warrant specific suggestions for future research. First, regarding the research design, the cross-sectional nature of the data restricts causal inferences. While Structural Equation Modeling verified the theoretical plausibility of the model, it cannot fully capture the developmental trajectory of these variables. Future research should employ longitudinal designs, such as autoregressive cross-lagged modeling, to rigorously examine how early cyberbullying experiences cumulatively impact attention and academic function over time.

Second, concerning measurement methods, reliance on self-report questionnaires may introduce subjectivity. To overcome potential reporting biases (e.g., social desirability or under-reporting of victimization), future studies should utilize multi-method assessment strategies. Specifically, computerized continuous performance tests (e.g., CPT) could be used to objectively measure attention deficits, while peer-nomination techniques or teacher ratings could provide a more accurate assessment of bullying victimization.

Third, the generalizability of the sample is limited. As this study was confined to elementary students in capital area by convenience sampling, it does not account for potential differences arising from regional or developmental contexts. Future research should expand the sampling to include diverse socio-economic backgrounds and conduct comparative studies with middle and high school students, given that the patterns and severity of cyberbullying often evolve during adolescence.

Fourth, the scope of variables requires expansion. While this study identified attention as a key mediator, emotional mechanisms also likely play a critical role. Future models should integrate internalizing problems, such as depression and anxiety, to test a dual-pathway model linking victimization to academic helplessness. Furthermore, it is crucial to identify protective factors (moderators), such as ego-resilience or teacher support, to provide practical implications for educational interventions designed to mitigate the negative impact of cyberbullying.

4.4. Conclusion

The core objective of the current study was to assess how cyberbullying victimization influences academic helplessness in elementary students, specifically focusing on the mediating role of attention problems. The results confirmed that cyberbullying victimization among elementary students can influence their academic helplessness, and that attention problems exert a significant mediating effect in this influencing process. The significance of this research lies in demonstrating that the recently escalating problem of cyberbullying extends beyond the immediate harm of victimization itself, potentially creating secondary problems such as academic helplessness. Furthermore, it clarifies that these secondary problems can be disseminated through the mediation of cognitive issues like attention problems. The findings of this study not only underscore the seriousness of cyberbullying victimization but also offer crucial educational implications: support for students who have been victimized by cyberbullying may need to extend beyond counseling or intervention focused solely on the bullying issue to encompass support for their academic and cognitive problems as well.

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6. Appendix

6.1. Author’s contribution

| | Initial name | Contribution |
|--------|--------------|--|
| Author | JC | <ul style="list-style-type: none"> -Set of concepts <input checked="" type="checkbox"/> -Design <input checked="" type="checkbox"/> -Getting results <input checked="" type="checkbox"/> -Analysis <input checked="" type="checkbox"/> -Make a significant contribution to collection <input checked="" type="checkbox"/> -Final approval of the paper <input checked="" type="checkbox"/> -Corresponding <input checked="" type="checkbox"/> -Play a decisive role in modification <input checked="" type="checkbox"/> -Significant contributions to concepts, designs, practices, analysis and interpretation of data <input checked="" type="checkbox"/> -Participants in Drafting and Revising Papers <input checked="" type="checkbox"/> -Someone who can explain all aspects of the paper <input checked="" type="checkbox"/> |

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Publisher: J-INSTITUTE
ISSN: 2189-7603

Website: j-institute.org

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DOI Address:
dx.doi.org/10.22471/crisis.2025.10.0.13



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A Structural Analysis of Ecological Resources and Visitor Pressure in Provincial Parks

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Abstract

Purpose: This study aims to identify the structural relationships between ecological resources and visitor pressure across 29 provincial parks in Korea. The analysis further seeks to compare characteristics across park types and derive management implications based on identified patterns. Given the wide variation in resource conditions and limited existing research, an integrated evaluation of ecological value and visitor infrastructure was required.

Method: Excluding one DMZ-adjacent park, 29 provincial parks were classified into four types—mountain, urban, coastal, and wetland. Indicators of ecological resources and visitor pressure were compiled and analyzed using descriptive statistics, ANOVA, and Pearson correlation analysis. This approach enabled a comprehensive assessment of re-source distributions, inter-type differences, and structural linkages among variables.

Results: Mountain-type parks exhibited the highest levels of ecological richness and visitor infrastructure, while coastal and wetland parks showed comparatively lower values. Strong positive correlations were identified among major indicators, including plant–animal species richness, trail length–segment count, and budget–staff capacity. These findings indicate that resources, use, and management systems operate in interdependent rather than isolated forms.

Conclusion: Ecological resources and visitor pressure differed significantly across park types, and clear structural linkages were observed among indicators. These results suggest the need for differentiated, type-specific management strategies rather than uniform approaches. Integrated systems connecting budget, staffing, and facilities were found to be essential for efficient park management.

Keywords: Provincial Parks, Ecological Resources, Visitor Pressure, Park Management, Correlation Analysis

1. Introduction

Provincial parks serve as representative regional protected areas that conserve ecological, geological, and landscape values while simultaneously providing opportunities for recreation and leisure[1]. Compared to national parks, provincial parks are generally more accessible and often located closer to residential areas[2], resulting in relatively high visitation frequencies by local residents and tourists. Consequently, achieving a balance between ecological conservation and visitor use has emerged as a critical challenge in provincial park management. In recent years, external drivers such as rapid urbanization, increasing ecological instability caused by climate change, and growing demand for nature-based outdoor activities have further heightened the importance of effective provincial park management.

Previous studies on protected area management have consistently emphasized the negative impacts of visitor activities on natural environments. Repeated trampling and facility use by visitors have been shown to induce trail surface erosion, soil compaction, scouring, and rock

exposure[3], which in turn lead to vegetation damage and deterioration of habitat quality. Heo and Yu(2015) reported that increased trail use intensity accelerates surface erosion and surrounding vegetation loss[4][5], while Lee et al.(2022) classified trail degradation into detailed types such as root exposure, trail widening, and surface erosion, providing important implications for management strategies[6]. In addition, You et al.(2011) demonstrated a close relationship between increasing visitor numbers and the spread of invasive alien plant species[7][8]. Studies conducted in national parks have further revealed that visitor pressure can contribute to habitat fragmentation, behavioral changes in wildlife, and simplification of species composition[9][10][11].

More recently, research on protected area management has shifted toward an integrated perspective, recognizing that ecological resources, visitor infrastructure, and management capacity operate as interconnected components within a unified system[12][13]. From this perspective, visitor-related elements, information facilities, staffing levels, and budgets should not be regarded as independent factors but rather as structurally linked to the ecological characteristics of each park[14]. Although this integrated approach has gained attention as a useful framework for evaluating the sustainability of protected areas, empirical studies in Korea have remained largely focused on national parks, with limited attention given to provincial parks[15][16].

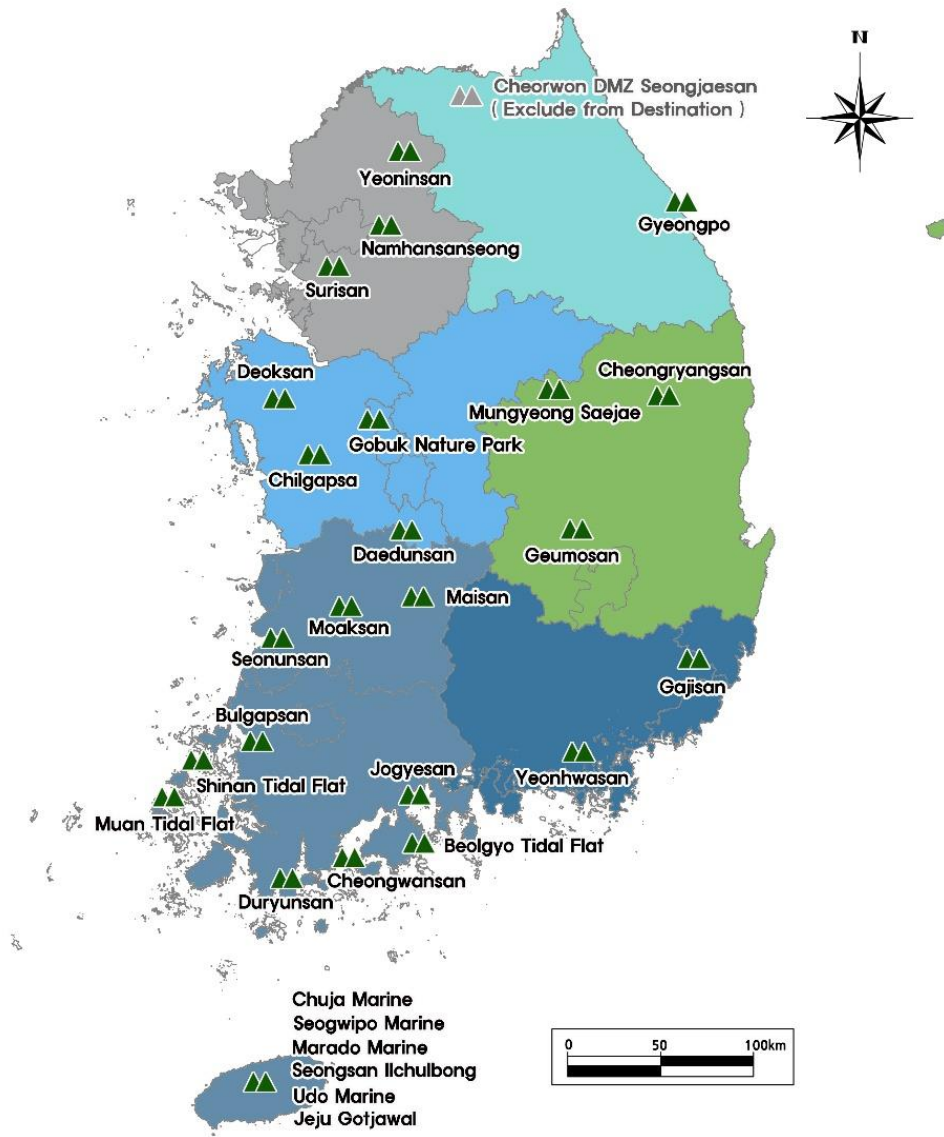
Provincial parks exhibit substantial heterogeneity in ecological resource endowment, visitor infrastructure, and management capacity[17], while the level of baseline data accumulation also varies considerably among parks. As a result, systematic comparative analyses have been difficult to conduct. Existing studies have tended to focus on individual parks or specific degradation factors, leaving a clear research gap in terms of comprehensive analyses that examine the structural relationships between ecological resource values and visitor pressure across provincial parks as a whole[18][19]. This gap has, in turn, constrained the development of evidence-based management policies for provincial parks.

In response to these limitations, this study aims to empirically examine the structural relationships between ecological resources and visitor pressure across 29 provincial parks nationwide by constructing a set of ecological resource and visitor pressure indicators. By identifying park-type specific characteristics and analyzing correlation structures among key variables, this study seeks to clarify how ecological value and visitor use interact within provincial parks. The findings are expected to provide foundational evidence for differentiated management strategies tailored to park types and to contribute to the development of management indicators and policy frameworks for provincial parks, particularly in the context of ecological tourism and sustainable park governance.

2. Study Area

The study area comprises 29 provincial parks across the Republic of Korea. Among the 30 designated provincial parks nationwide, one park Cheorwon DMZ Seongjaesan Provincial Park was excluded from the analysis due to insufficient availability of ecological and visitor use data. Provincial parks located within or adjacent to the Demilitarized Zone (DMZ) and civilian control areas are subject to military and administrative restrictions, which have been reported to hinder long-term ecological surveys and systematic accumulation of visitor statistics[20][21]. To ensure analytical consistency and data reliability, this park was therefore excluded from the study <Figure 1>.

Figure 1. Location map of provincial parks.



Compared to national parks, provincial parks represent a mid-level category of protected areas that play a critical role in conserving regional ecosystems while simultaneously supporting recreational use by local residents[6]. However, provincial parks exhibit substantial heterogeneity in terms of natural environmental conditions, spatial settings, ecological resource endowment, and visitor-use intensity[22]. Such heterogeneity poses a challenge to the application of uniform management standards and underscores the necessity of spatially differentiated analytical approaches in provincial park research.

In this study, provincial parks were classified into four types mountain-type, urban-type, coastal-type, and wetland-type based on geomorphological characteristics, locational context, dominant ecosystem types, and visitor-use patterns[1][15]. This classification framework has been widely adopted in previous studies and administrative practices as an effective means of interpreting ecological and managerial characteristics of provincial parks[23][24][25]. By applying this typology, the present study aims to provide a structured basis for comparing ecological resources and visitor pressure across parks with distinct environmental and spatial conditions.

Mountain-type provincial parks are characterized by pronounced elevation gradients, complex topography, and forest dominated ecosystems, often supporting high levels of biodiversity[26]. These parks tend to have extensive trail networks with multiple branching points, reflecting strong visitor demand for hiking and scenic experiences. Consequently, trail degradation, erosion control, and visitor safety management emerge as key management concerns in these areas[27]. Urban-type provincial parks, typically located near metropolitan areas, exhibit high accessibility and visitation frequency. In such parks, recreational, scenic, and everyday leisure functions are often emphasized over strict ecological conservation, resulting in distinctive visitor pressure patterns[28].

Coastal-type provincial parks encompass coastal landforms such as shorelines, sand dunes, and rocky coasts, along with specialized ecosystems adapted to saline exposure, strong winds, and unstable substrates[29][30]. These environmental constraints often limit species richness; however, the high visual and recreational value of coastal landscapes leads to concentrated seasonal visitation. Wetland-type provincial parks are centered on rivers, lakes, and wetland ecosystems and are characterized by high ecological sensitivity[31]. Even minor environmental disturbances in these areas can trigger significant ecological impacts, necessitating stringent access control, minimal trail development, and seasonally adaptive management strategies.

This typological classification serves not merely as a spatial categorization but as a core analytical framework for interpreting differences in ecological resource composition and visitor pressure structures among provincial parks. By examining the distribution patterns of ecological and visitor-related indicators within this framework, the present study seeks to empirically assess the necessity of differentiated management strategies that reflect park-specific environmental conditions. Ultimately, this approach aims to derive policy-relevant insights that acknowledge the regional diversity and varying management contexts of provincial parks.

3. Methods

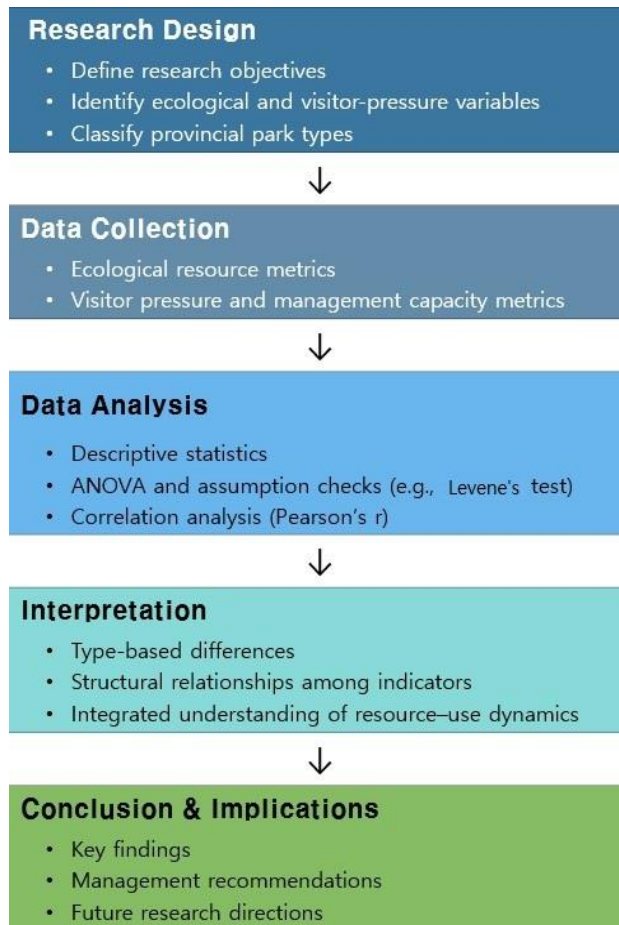
This study proceeded through three stages:

- (1) construction of ecological resource and visitor pressure datasets,
- (2) descriptive statistics and ANOVA-based comparison across park types, and
- (3) correlation analyses to examine structural relationships among variables.

Ecological resource indicators included plant species richness, animal species richness, endangered species counts, cultural resources, and scenic resources. These indicators capture both biological and landscape-based ecological values of provincial parks. Visitor pressure indicators included trail length, trail segment count, visitor center area, number of management staff, annual budget, public restrooms, and signage—metrics reflecting both visitor use intensity and management capacity.

Descriptive statistics were used to examine mean values and variance across indicators. One-way ANOVA was applied to test differences across park types with a significance level of $p < .05$. Pearson correlation analysis was conducted to evaluate potential structural linkages within ecological indicators, within visitor-pressure indicators, and between the two groups. This analytic process provides foundational insight into the integrated dynamics of resources, use, and management within provincial parks. The research flow is illustrated in <Figure 2>.

Figure 2. Research framework.



4. Results

4.1. Ecological resources and differences by park type

Descriptive statistics for ecological resources are presented in <Table 1>. Across all parks, the average plant species count was 465.7, and animal species averaged 429.4, indicating relatively high biodiversity. Endangered species averaged 9.5 across parks, reaffirming the ecological significance of provincial parks. Scenic resource scores averaged 3.2, suggesting that most parks possess notable landscape value.

Table 1. Ecological resources by park type.

| Variable | Mean | SD | Min | Max |
|--------------------|-------|-------|-----|------|
| Plant Species | 465.7 | 385.2 | 0 | 1278 |
| Animal Species | 429.4 | 350.4 | 67 | 1302 |
| Endangered Species | 9.5 | 12.7 | 0 | 67 |
| Cultural Resources | 30.1 | 79. | 0 | 425 |
| Scenic Resources | 18.2 | 18.6 | 1 | 72 |

Type-based comparisons are summarized in <Table 2>. Mountain-type parks showed the highest plant (652 species) and animal (553 species) richness, attributable to altitudinal variation, microhabitat diversity, and complex terrain. Coastal parks exhibited comparatively low species richness, likely due to environmental constraints such as salinity exposure, wind stress, and sandy soils.

ANOVA results indicated significant differences in plant species ($F=5.463$, $p=.005$), animal species ($F=6.084$, $p=.003$), and scenic resources ($F=3.571$, $p=.028$), suggesting that ecological resource levels are shaped more by environmental and landscape conditions than by protection status or park size.

Table 2. Ecological correlation matrix.

| Technical statistics table | | | | | | | | | | | |
|----------------------------|----|---------------|-------|----------------|-------|--------------------|------|--------------------|------|---------------------|------|
| Type | N | Plant species | | Animal species | | Endangered species | | Cultural resources | | Landscape resources | |
| | | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Mountain | 18 | 652.9 | 356.6 | 553.8 | 383.8 | 7.2 | 5.6 | 45.6 | 99.1 | 25.8 | 19.6 |
| Urban | 1 | 633.0 | . | 526.0 | . | 10.0 | . | 20.0 | . | 13.0 | . |
| Coastal | 8 | 84.1 | 87.3 | 178.4 | 112.1 | 13.5 | 22.1 | 3.8 | 3.8 | 6.3 | 7.2 |
| Wetland | 2 | 224.0 | 18.4 | 266.5 | 29.0 | 14.0 | 17.0 | 1.0 | 1.4 | 1.0 | .0 |
| Sum | 29 | 465.7 | 385.2 | 429.4 | 350.4 | 9.5 | 12.7 | 30.1 | 79.9 | 18.2 | 18.6 |

Levene's test for homogeneity of variances
 Plant species: $F=5.463$, $df1=3$, $df2=25$, $p=.005$
 Animal species: $F=6.084$, $df1=3$, $df2=25$, $p=.003$
 Endangered species: $F=2.553$, $df1=3$, $df2=25$, $p=.078$
 Cultural resources: $F=1.288$, $df1=3$, $df2=25$, $p=.300$
 Landscape resources: $F=3.571$, $df1=3$, $df2=25$, $p=.028$

4.2. Visitor pressure characteristics and type-based differences

Descriptive statistics for visitor pressure indicators are shown in <Table 3>. The average trail length was 24.6 km, with mountain-type parks exhibiting the longest average trail networks (33.2 km). Coastal and wetland parks had limited trail development due to natural constraints.

Visitor center area, staff size, and budget also varied significantly by park type. Mountain parks maintained the highest levels of management capacity, while coastal and wetland parks possessed comparatively limited resources.

ANOVA results for visitor pressure indicators are presented in <Table 4>. Trail length ($F=4.901$, $p=.008$) and trail segment count ($F=3.957$, $p=.019$) differed significantly among park types, demonstrating fundamentally different patterns of visitor use and facility development.

Table 3. Visitor pressure by park type.

| Variable | Mean | SD | Min | Max |
|---------------------------------------|-----------|-----------|-----|------------|
| Trail length (km) | 24.6 | 24.2 | 0 | 88.3 |
| Number of trail sections | 10.2 | 12.1 | 0 | 58.0 |
| Visitor center area (m ²) | 384.6 | 844.7 | 0 | 4120.0 |
| Management staff | 12.7 | 17.1 | 0 | 84.0 |
| Annual budget | 2006538.2 | 3000377.1 | 0 | 12500434.0 |

| | | | | |
|------------------|------|------|---|-------|
| Public restrooms | 8.5 | 7.5 | 1 | 28.0 |
| Signage | 79.9 | 69.6 | 0 | 297.0 |

Table 4. Visitor pressure correlation matrix.

| Technical statistics table | | | | | | | | | |
|----------------------------|----|-------------------|-----------|--------------------------|------|---------------------------------------|--------|------------------|------|
| Type | N | Trail length (km) | | Number of trail sections | | Visitor center area (m ²) | | Management staff | |
| | | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Mountain | 18 | 33.2 | 19.0 | 12.2 | 7.5 | 345.3 | 520.2 | 11.9 | 8.0 |
| Urban | 1 | 88.3 | . | 58.02 | . | 733.1 | . | 84.0 | . |
| Coastal | 8 | 2.1 | 3.0 | 1.9 | 3.4 | 525.5 | 1452.7 | 7.5 | 15.2 |
| Wetland | 2 | 5.7 | 3.0 | 1.5 | .7 | .0 | .0 | 4.5 | .7 |
| Sum | 29 | 24.6 | 24.2 | 10.2 | 12.1 | 384.6 | 844.7 | 12.7 | 17.1 |
| Type | N | Annual budget | | Public restrooms | | Signage | | | |
| | | Mean | SD | Mean | SD | Mean | SD | | |
| Mountain | 18 | 2471767.4 | 2942784.2 | 9.2 | 6.8 | 86.5 | 48.2 | | |
| Urban | 1 | 10482809.0 | . | 19.0 | . | 212.0 | . | | |
| Coastal | 8 | 265401.8 | 263912.4 | 6.8 | 9.3 | 56.3 | 100.7 | | |
| Wetland | 2 | 545885.5 | 306018.1 | 3.5 | .7 | 48.5 | 23.3 | | |
| Sum | 29 | 2006538.2 | 3000377.1 | 8.5 | 7.5 | 79.9 | 69.6 | | |

Levene's test for homogeneity of variances

Trail length (km) : F=4.901, df1=3, df2=25, p=.008

Number of trail sections : F=3.957, df1=3, df2=25, p=.019

Visitor center area (m²) : F=1.843, df1=3, df2=25, p=.165

Management staff : F=1.105, df1=3, df2=25, p=.366

Annual budget : F=2.615, df1=3, df2=25, p=.073

Public restrooms : F=1.663, df1=3, df2=25, p=.200

Signage : F=1.109, df1=3, df2=25, p=.364

4.3. Correlation analysis of ecological resource indicators

Correlation results for ecological indicators are summarized in <Table 5>. Strong positive correlations were observed between plant and animal species richness ($r = .732$, $p < .001$), reflecting ecological interactions and habitat diversity. Significant correlations between plant species and scenic resources ($r = .600$, $p = .001$) also suggest that visually diverse landscapes often coincide with ecological richness.

Cultural resources showed weak correlations with ecological measures, indicating that cultural-historical features are largely independent of natural ecosystem attributes.

Table 5. Ecological resource correlations.

| Variable | Mean | SD | Correlation | | | | |
|----------------|---------|----------|-------------|------|------|------|------|
| | | | 1(p) | 2(p) | 3(p) | 4(p) | 5(p) |
| Plant species | 465.724 | 385.2281 | 1 | | | | |
| Animal species | 429.448 | 350.4213 | .732(.000) | 1 | | | |

| | | | | | | | |
|--------------------|--------|---------|------------|-------------|-------------|------------|---|
| Endangered species | 9.517 | 12.6762 | .024(.902) | -.027(.889) | 1 | | |
| Cultural resources | 30.103 | 79.8970 | .364(.052) | .060(.758) | .001(.998) | 1 | |
| Scenic resources | 18.241 | 18.6254 | .600(.001) | .527(.003) | -.037(.850) | .204(.289) | 1 |

4.4. Correlation analysis of visitor pressure indicators

Visitor pressure correlations are displayed in <Table 6>. Trail length and trail segments showed a strong positive correlation ($r = .814$, $p < .001$), indicating that trails develop as interconnected networks rather than isolated routes. Budget and staffing were also strongly correlated ($r = .703$, $p < .001$), reflecting the integral relationship between financial and human resources.

Significant correlations were additionally observed between visitor center area and signage, highlighting the integrated nature of visitor information systems.

Table 6. Visitor pressure correlations.

| Variable | Mean | SD | Correlation | | | | | | |
|---------------------------------------|-------------|-------------|-------------|------------|-------------|------------|------------|------------|------|
| | | | 1(p) | 2(p) | 3(p) | 4(p) | 5(p) | 6(p) | 7(p) |
| Trail length (km) | 24.6276 | 24.16000 | 1 | | | | | | |
| Number of trail sections | 10.172 | 12.1098 | .814(.000) | 1 | | | | | |
| Visitor center area (m ²) | 384.5552 | 844.66854 | .108(.578) | .014(.944) | 1 | | | | |
| Management staff | 12.690 | 17.0589 | .513(.004) | .692(.000) | .020(.916) | 1 | | | |
| Annual budget | 2006538.172 | 3000377.073 | .461(.012) | .570(.001) | -.032(.868) | .703(.000) | 1 | | |
| Public restrooms | 8.483 | 7.4910 | .253(.185) | .313(.098) | -.170(.377) | .435(.018) | .563(.001) | 1 | |
| Signage | 79.862 | 69.6336 | .548(.002) | .381(.041) | .734(.000) | .379(.043) | .317(.094) | .026(.893) | 1 |

5. Conclusion

This study quantitatively analyzed the composition of ecological resources and the structure of visitor pressure in 29 provincial parks across Korea, revealing clear park-type specific characteristics and significant structural linkages among key variables. The results demonstrate that both ecological resources and visitor pressure vary markedly according to park type and that ecological, visitor, and management indicators are strongly interconnected. These findings suggest that provincial parks function not merely as protected natural spaces but as complex systems in which ecological conservation, visitor use, and management capacity interact dynamically.

First, the findings indicate that provincial park management policies should move beyond uniform standards and adopt park-type-specific management strategies. Mountain-type parks exhibited high levels of both ecological resources and visitor infrastructure, implying that trail degradation control, safety facility maintenance, and visitor dispersion strategies should be prioritized. For example, a differentiated trail management scenario may be applied in which high-use trail segments are reinforced through boardwalk installation, surface stabilization, and de-tour routes, while low-use areas are managed under a natural recovery-oriented approach.

In contrast, coastal and wetland-type parks showed relatively lower levels of ecological resources and visitor infrastructure but were characterized by high ecological sensitivity. For these park types, management scenarios emphasizing access control and clear zoning of permissible visitor areas are likely to be more effective than infrastructure expansion. In wetland-type provincial parks, policy applications such as seasonal access restrictions based on ecological sensitivity, floating boardwalks to disperse trampling pressure, and advance reservation systems for visitors may be introduced. Such approaches can help maintain visitor satisfaction while minimizing ecological disturbance.

Second, the strong correlations among ecological resource indicators underscore the importance of habitat scale integrated management policies. The close relationships among plant species richness, animal species richness, and landscape resources indicate that conservation strategies focusing on habitat complexity and landscape level integrity may be more effective than species-specific interventions. From a policy perspective, this supports the application of zone-based management scenarios, in which core conservation areas centered on endangered species habitats are surrounded by buffer zones with progressively regulated visitor activities.

Third, the structural interconnections among visitor pressure indicators highlight the need for integrated operation of budgets, staffing, and facilities in provincial park management. The strong correlations among budget allocation, management personnel, and visitor infrastructure suggest that fragmented investment strategies are unlikely to be effective. Instead, a package-based investment scenario where new trail development is accompanied by staffing reinforcement, monitoring equipment installation, and improvements to visitor information systems should be considered. Such integrated investment approaches are expected to enhance long-term management efficiency and cost effectiveness.

Fourth, the results provide implications for improving provincial park evaluation frameworks. Current evaluation practices tend to rely on absolute indicators such as facility counts or total budgets; however, future frameworks should incorporate composite and relative indicators that reflect the structural relationships between ecological resources and visitor pressure. Indicators such as trail density relative to species richness or visitor numbers relative to management staff may offer more objective measures of management burden and sustainability.

Finally, although this study provides valuable baseline evidence for provincial park management, it also has limitations. Because the analysis focused primarily on correlation structures, causal relationships among variables could not be directly identified. Future research should employ advanced analytical techniques, such as principal component analysis (PCA), regression analysis, and spatial analysis, to further explore causal mechanisms. In addition, longitudinal studies based on long-term monitoring data would enable evaluation of management policy effectiveness over time and contribute to the development of adaptive management strategies for provincial parks.

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7. Appendix

7.1. Author's contribution

| | Initial name | Contribution |
|--------|--------------|--|
| Author | HL | <ul style="list-style-type: none"> -Set of concepts <input checked="" type="checkbox"/> -Design <input checked="" type="checkbox"/> -Getting results <input checked="" type="checkbox"/> -Analysis <input checked="" type="checkbox"/> -Make a significant contribution to collection <input checked="" type="checkbox"/> -Final approval of the paper <input checked="" type="checkbox"/> -Corresponding <input checked="" type="checkbox"/> -Play a decisive role in modification <input checked="" type="checkbox"/> -Significant contributions to concepts, designs, practices, analysis and interpretation of data <input checked="" type="checkbox"/> -Participants in Drafting and Revising Papers <input checked="" type="checkbox"/> -Someone who can explain all aspects of the paper <input checked="" type="checkbox"/> |

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Publisher: J-INSTITUTE
ISSN: 2189-7603

Website: j-institute.org

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E-mail: hjh44@daum.net

DOI Address:
dx.doi.org/10.22471/crisis.2025.10.0.25



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Current Status and Improvement Directions of Care Policies in Areas Facing Aging Population

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Abstract

Purpose: This study aimed to investigate the current status of elderly care service provision in a hyper-aged society and to provide foundational evidence for the development of elderly care policies.

Method: A descriptive cross-sectional study design was employed using secondary data from 2022 to 2023. The study population included adults aged 65 years and older residing in Province J. Data were obtained from publicly available sources, including the National Health Insurance Service, the Ministry of Health and Welfare, and local government statistics related to long-term care insurance, customized elderly care services, and elderly welfare services. Variables analyzed included long-term care eligibility, service utilization rates, caregiving types, and the size of care blind spots. Descriptive statistical analyses were conducted using frequencies, per-centages, and estimated population ranges.

Results: Approximately 68,000 older adults in Province J were eligible for long-term care services, accounting for 16.24% of the elderly population, which is about 4 percentage points higher than the national average. The total number of users of long-term care and customized elderly care services was approximately 97,000, representing 23.04% of the elderly population. The private caregiving rate was high at 61.2%, with family caregiving accounting for 53.9%, paid caregiving for 2.9%, and other caregiving for 4.4%. An estimated 9,700 older adults were identified as being in care blind spots, with the number increasing with age. In addition, approximately 21,000 older adults were estimated to be in dementia-related care blind spots. The total number of elderly individuals utilizing care services ranged from 96,000 to 121,000.

Conclusion: As the transition to a super-aged society accelerates, a substantial proportion of older adults remain outside the formal care system. These findings highlight the need for a rational assessment system to identify care needs accurately and to provide customized care based on functional status. Furthermore, the establishment of integrated community-based care centers and sustainable public-private partnerships is essential to reduce care blind spots and strengthen elderly care service delivery.

Keywords: Elderly, Super-Aged Society, Tailored, Care Services, Long-Term Care Services

1. Introduction

1.1. Need for the study

South Korea has entered a super-aged society, with those aged 65 and over accounting for 20.3% of the total population an unprecedented rate of change [1]. This proportion is projected to exceed 30% by 2036 and 40% by 2050 [2]. Projections indicate that the pace of super-aging will accelerate further. The super-aging of the elderly population will inevitably lead to increased demand for their healthcare [3]. Health issues in the elderly differ from those in younger adults, presenting complex disease manifestations, and even within the normal aging process, physical

functions gradually decline [4]. Therefore, understanding the elderly requires broad understanding and a comprehensive approach [5]. The increase in the elderly population has a significant impact on the lives of seniors across all aspects of the community, including health, medical care, education, and culture [6]. Unlike urban areas, rural regions have weak health and welfare infrastructure and insufficient access to institutionalized nursing and care services [7]. However, population aging has reached a physical limit where institutional solutions like nursing facilities can no longer adequately meet the demand for elderly care [7].

The regions with the highest aging rates for those aged 65 and over were Jeollanam-do at 27.2%, Gyeongsangbuk-do at 26%, Jeollabuk-do at 25.3%, Gangwon-do at 25.4%, and Busan at 23.9%. The regions with the lowest aging rates were Sejong at 11.6%, Gyeonggi-do at 16.6%, Ulsan at 17.2%, Gwangju at 17.5%, and Incheon at 17.7%. While the metropolitan area (particularly parts of Gyeonggi, Incheon, and Seoul) remains relatively young, the provinces (South Jeolla, North Jeolla, North Gyeongsang, etc.) already face a severe situation with over 25% of their populations being elderly [8]. Aging increases susceptibility to disease onset, leading to heightened risks of acute and chronic illnesses in later life. This often results in the accumulation of multiple comorbidities, whose complications—alongside frailty symptoms inherent to advanced age—inevitably diminish daily living functions. The health status of the elderly in our country is extremely poor, with at least 84% of all seniors suffering from one or more chronic diseases. The average number of chronic conditions per senior is reported to be 1.9, and there appears to be little prospect of significant improvement in the foreseeable future [9], and it appears unlikely to improve significantly in the foreseeable future. The increase in the elderly population leads to a social burden due to the rise in chronic diseases [10].

As the super-aging of the elderly population accelerates, medical expenses are also increasing, undermining the sustainability of the social security system. Meanwhile, initiatives to improve the health behaviors of the elderly or provide systematic health management remain inadequate [11], an increase in the number of elderly requiring long-term care, and longer care periods.

Moreover, elderly individuals in rural areas often live far from their children, resulting in a weak support system [12]. Depending on their physical capabilities, their dependence increases in daily activities such as dressing, eating, using the restroom, moving around, and bathing [13][14]. Such assistance with activities of daily living provided to seniors at day and night care facilities requires proactive coordination to enable access to integrated long-term care benefits services, such as home care and home bathing services [15].

This phenomenon is accelerating the emergence of elderly individuals living alone or in single-elderly households faster than anticipated, while simultaneously causing a rapid decline in the ability of families to provide support and care. Therefore, in this rapidly aging society, it is necessary to assess the current state of care provided to these individuals to ensure their health promotion and safety. This study aims to investigate the current status of care services for elderly individuals in the Jeollabuk-do region, who constitute a care-dependent population, and to present this as foundational data for developing programs tailored to their needs.

2. Current Status and Key Contents of Elderly Care Policies in Specific Area

Long-term care services for the elderly are broadly categorized into elderly long-term care services, customized elderly care services, emergency safety services, pilot projects for elderly medical care, and meal support programs for the elderly. Customized elderly care services provide direct support and linked services such as housing improvements, health support, and daily living assistance to individuals aged 65 and over who are recipients of basic livelihood security benefits, those in the next-lowest income bracket, and basic pension recipients. Long-term care

services for the elderly provide facility-based care services such as home-visit nursing, home-visit bathing, and admission to elderly care facilities for individuals aged 65 and older, or those under 65 with age-related illnesses, who have been assigned a care level [16].

2.1. Current status of elderly long-term care service assessment

The number of individuals assessed for long-term care services for the elderly in Jeonbuk Special Self-Governing Province, including those not assigned a grade, totals approximately 68,000, accounting for about 16.24% of the total elderly population. Excluding those not assigned a grade, the number of individuals assigned a grade totals approximately 59,000, accounting for about 13.98% of the total elderly population. As of the end of 2023, the ratio of individuals assessed for long-term care services in Jeonbuk Special Self-Governing Province stands at 16.24%, which is over 4 percentage points higher than the national average of 12.24%. Furthermore, the proportion of graded elderly individuals in Jeonbuk Special Self-Governing Province is 13.98%, which is also over 3 percentage points higher than the national average of 10.9%. The proportion of individuals receiving long-term care service grade assessments in Jeonbuk Special Self-Governing Province is the second highest after Jeonnam's 16.49%, and the proportion of elderly individuals within each grade is also the highest after Jeonnam's 14.12%.

Looking at the grade composition of long-term care recipients in Jeonbuk Special Self-Governing Province, Grade 1 accounts for 2.54% and Grade 2 for 5.44%, with the proportion of severe cases at approximately 8%. This is relatively lower than the national average of 4.09% for Grade 1 and 7.89% for Grade 2 <Table 1>.

Therefore, given that non-graded seniors among long-term care service recipients represent a blind spot in care services, it is necessary to develop comprehensive care policies targeting non-graded seniors during the planning process for future Jeonbuk-style care services.

Table 1. Current status of long-term care service assessment for elderly individuals aged 65 and over. (Unit : N, %)

| Category | Total | Grade 1 | Grade 2 | Grade 3 | Cognitive Support | | | Unrated | Rated | All elderly people | Rated elderly rate | All Rater rate |
|--------------|-----------|---------|---------|---------|-------------------|---------|--------|---------|---------|--------------------|--------------------|----------------|
| | | | | | Grade 4 | Grade 5 | Grade | | | | | |
| Total | 1,191,487 | 48,696 | 94,044 | 286,514 | 486,506 | 121,112 | 24,773 | 129,842 | 1061645 | 9,730,411 | 10.91 | 12.24 |
| (Percentage) | 100.00 | 4.09 | 7.89 | 24.05 | 40.83 | 10.16 | 2.08 | 10.90 | 89.10 | - | - | - |
| Chungbuk | 44,361 | 1,767 | 3,683 | 10,607 | 17,726 | 5,225 | 1,160 | 4,193 | 40168 | 332,237 | 12.09 | 13.35 |
| Chungnam | 67,080 | 2,447 | 4,915 | 15,134 | 27,502 | 7,897 | 1,837 | 7,348 | 59732 | 454,534 | 13.14 | 14.76 |
| Jeonbuk | 68,737 | 1,745 | 3,742 | 11,774 | 29,999 | 10,363 | 1,513 | 9,601 | 59136 | 423,128 | 13.98 | 16.24 |
| (Percentage) | 100.00 | 2.54 | 5.44 | 17.13 | 43.64 | 15.08 | 2.20 | 13.97 | 86.03 | - | - | - |
| Jeonnam | 77,625 | 2,089 | 5,034 | 14,516 | 33,865 | 9,214 | 1,764 | 11,143 | 66482 | 470,874 | 14.12 | 16.49 |
| Jeju | 12,630 | 1,009 | 1,371 | 3,556 | 4,106 | 988 | 300 | 1,300 | 11330 | 121,156 | 9.35 | 10.42 |

Note: Source: National health insurance service (2023), long term insurance statistical yearbook (2024).

2.2. Current status of customized care services for the elderly

The total number of users of long-term care services and customized elderly care services in Jeonbuk Special Self-Governing Province is 97,000, representing approximately 23.04% of the total elderly population utilizing care services <Table 2>.

Table 2. Current status of elderly customized care service users.

(Unit : N, %)

| Category | Jeonbuk | Total elderly population [㉑] | Customized Senior Care [㉒] | Long-term care services [㉓] | Elderly individuals using care services [㉔=㉒+㉓] | Care Service Utilization Rate |
|----------|-----------|---------------------------------|-------------------------------|--------------------------------|--|-------------------------------|
| Total | 1,754,757 | 423,128 | 38,184 | 59,286 | 97,470 | 23.04 |

Note: Source: Study on the establishment and operation of a jeonbuk-style stonefish system (2024).

2.3. Private caregiving rate in Jeonbuk special autonomous province

A significant care gap in establishing the Jeonbuk-type care system is the users of private nursing care for hospitalized patients, which is not provided by current care services. Among all hospitalized patients, the private nursing care rate reaches 61.2%. Of this 61.2%, paid nursing care accounts for 2.9%, family nursing care for 53.9%, and other nursing care for 4.4%.

Based on the private caregiving rate, the estimated scale of private caregivers in Jeonbuk Special Self-Governing Province is as follows: approximately 254,000 hospitalized patients utilize private caregiving. Within this group, paid caregivers serve about 12,000 patients, family caregivers serve 224,000 patients, and other caregivers serve approximately 19,000 patients. Under the current care service system, national programs such as the Long-Term Care Insurance and the Senior Care Service are implemented for those aged 65 and older, providing care for a certain portion of the elderly in this age group. However, for hospitalized patients under 65, it is evident that care services remain unavailable for temporary care during the recovery period after discharge, hospital accompaniment, or nursing care during hospitalization.

For individuals aged 65 and older, long-term care insurance provides some care services, but family caregiving remains the most common form of private caregiving <Table 3>.

Table 3. 2021 current status of inpatients and estimated private caregivers in Jeonbuk special autonomous province.

(Unit : N)

| Category | | Total | 0~19 | 20~39 | 40~64 | 50~64 | ≥65 | 65~79 | ≥80 |
|---------------------|-------------------------------|---------|--------|--------|---------|---------|---------|---------|--------|
| Hospitalized person | Man | 191,136 | 23,465 | 23,620 | 72,552 | 52,250 | 71,499 | 52,112 | 19,387 |
| | Female | 219,273 | 19,741 | 30,255 | 78,845 | 56,786 | 90,432 | 57,162 | 33,270 |
| | Total | 410,409 | 43,206 | 53,875 | 151,397 | 109,036 | 161,931 | 109,274 | 52,657 |
| Private care rate | Total (61.2) | 254,043 | 26,745 | 33,349 | 93,715 | 67,493 | 100,235 | 67,641 | 32,595 |
| | Paid Caregiving Rate (2.9) | 11,902 | 1,253 | 1,562 | 4,391 | 3,162 | 4,696 | 3,169 | 1,527 |
| | Family caregiving rate (53.9) | 223,673 | 23,547 | 29,362 | 82,511 | 59,425 | 88,252 | 59,554 | 28,698 |
| | Other Caregiving Rates (4.4) | 18,879 | 1,987 | 2,478 | 6,964 | 5,016 | 7,449 | 5,027 | 2,422 |

| | | | | | |
|-----------------------|---|---|--|---|---|
| Care demand | - | Hospital accompaniment hospitalization care | . Hospitalization and caregiving . Temporary care for a period before and after discharge | - | - |
| Related care policies | - | . Childcare | | . Long-term care insurance . Senior-tailored care services | - |
| | | . Home care and nursing support program | | | |

Note: Source: Study on the establishment and operation of a jeonbuk-style stonefish system (2024).

2.4. Demand for elderly care

The Jeonbuk-type elderly care service primarily provides basic care services centered on the state-led long-term care insurance system. However, care services are only provided to elderly individuals who have applied for long-term care insurance and received a grade assessment, leaving a significant number of elderly people in need of care in a blind spot. The gaps in the elderly long-term care system are primarily categorized as follows: elderly individuals who require care but have not applied, applicants who did not receive a care level assessment, and those who received an assessment but did not utilize long-term care services <Table 4>.

Table 4. Estimation of care gaps for the elderly under the long-term care system.

(Unit : N)

| Category | | Total | <65 | 65~69 | 70~74 | 75~79 | 80~84 | ≥85 |
|--|----------|--------|-----|-------|-------|-------|-------|-------|
| Care Blind spot (A) Applicant-Individuals who have been assigned a grade | Chungbuk | 6,358 | 358 | 765 | 935 | 1,426 | 1,589 | 1,285 |
| | Chungnam | 10,015 | 496 | 1,044 | 1,545 | 2,232 | 2,464 | 2,234 |
| | Jeonbuk | 9,717 | 471 | 1,008 | 1,477 | 2,211 | 2,471 | 2,079 |
| | Jeonnam | 11,525 | 449 | 1,101 | 1,671 | 2,574 | 3,049 | 2,681 |
| | Jeju | 2,396 | 135 | 229 | 300 | 461 | 587 | 684 |
| Care Blind spot (A) Applicant- People within the grade * 1~5+ Cognitive Support grade | Chungbuk | 10,926 | 671 | 1,361 | 1,679 | 2,455 | 2,693 | 2,067 |
| | Chungnam | 18,066 | 930 | 2,048 | 2,729 | 4,092 | 4,562 | 3,705 |
| | Jeonbuk | 20,507 | 986 | 2,761 | 3,526 | 4,770 | 4,838 | 3,626 |
| | Jeonnam | 23,851 | 945 | 2,545 | 3,656 | 5,570 | 6,215 | 4,920 |
| | Jeju | 3,914 | 240 | 439 | 530 | 789 | 938 | 978 |

Note: Source: National health insurance service (2023), study on the establishment and operation of a jeonbuk-style stonefish system (2024).

2.5. Current status of care gaps for dementia under long-term care insurance

The coverage gap in the Long-Term Care Insurance for the Elderly, based on the number of applicants who are not certified care recipients, is estimated to be approximately 9,000 people in Jeonbuk Special Self-Governing Province.

Furthermore, estimating the care gap based on applicants within the graded assessment system suggests approximately 21,000 individuals in Jeonbuk Special Self-Governing Province. Thus, the care gap in the long-term care system in Jeonbuk Special Self-Governing Province is estimated to range from a minimum of approximately 9,000 to a maximum of approximately 30,000 individuals. Meanwhile, estimating the care gap for dementia patients in long-term care services

reveals that among registered dementia patients, only 22,000 were utilizing long-term care services as of the end of 2022. This indicates that approximately 23,000 registered dementia patients are in the care gap of the long-term care system <Table 5>.

Table 5. Care gaps for dementia under long-term care insurance. (Unit : N)

| Category | Dementia-registered population [A] | Elderly population | Status of long-term care grade recipients | | | | | | | Cognitive Support Level [f] | Dementia long-term care recipient | Long-term care blind spots for dementia patients |
|----------|------------------------------------|--------------------|---|------------|------------|------------|------------|------------|-------|-----------------------------|-----------------------------------|--|
| | | | Total | Grade 1(a) | Grade 2(b) | Grade 3(c) | Grade 4(d) | Grade 5(e) | | | | |
| Chungbuk | 22,309 | 332,237 | 41,793 | 1,657 | 3,757 | 10,203 | 16,311 | 4,567 | 1,043 | 15,957 | 21,581 | |
| Chungnam | 37,183 | 454,534 | 63,805 | 2,306 | 4,848 | 14,327 | 25,852 | 7,180 | 1,675 | 22,777 | 33,411 | |
| Jeonbuk | 44,737 | 423,128 | 66,244 | 1,685 | 3,770 | 11,299 | 28,189 | 9,717 | 1,309 | 21,874 | 34,095 | |
| Jeonnam | 44,928 | 470,874 | 73,833 | 1,932 | 4,844 | 13,688 | 31,522 | 8,302 | 1,715 | 24,592 | 37,411 | |
| Jeju | 7,582 | 121,156 | 12,198 | 907 | 1,411 | 3,336 | 3,956 | 898 | 277 | 5,074 | 5,711 | |

Note: Source: National health insurance service (2023), study on the establishment and operation of a jeonbuk-style stonefish system (2024).

2.6. Current status of elderly care service utilization

As of the end of 2022, the number of applicants for long-term care insurance in Jeonbuk Special Self-Governing Province was 78,000, of whom approximately 75,000 were seniors aged 65 or older. Among the entire senior population, the total number of care service users—including long-term care insurance, senior-tailored services, and senior welfare facilities—ranges from a minimum of 96,000 to a maximum of 121,000 <Table 6>.

Table 6. Current status and utilization rate of elderly care service users. (Unit : N)

| Category | Long-term care insurance [A] | | | Elderly-specific care [B] | | | Elderly welfare facility users [C] | | | Elderly care [D] (A+B) | Elderly care [E] (A+B+C) | Total elderly population [F] | Rate | |
|----------|------------------------------|---|--------------------------|---------------------------|---------------------|--------|------------------------------------|------------------------------------|------------------------------------|------------------------|--------------------------|------------------------------|------|------|
| | Applicant | Individual who have been assigned a grade | Certified Grade Assessor | General Care Group | Priority Care Group | Total | Senior Housing Welfare Facilities | Elderly Medical Welfare Facilities | Welfare facilities for the elderly | | | | D/F | E/F |
| Chungnam | 75,834 | 65,819 | 57,768 | 29,350 | 3,169 | 32,519 | 275 | 10,062 | 12,389 | 90,287 | 113,013 | 436,895 | 2067 | 2587 |
| Jeonbuk | 78,151 | 68,434 | 57,644 | 33,158 | 5,331 | 38,489 | 1,484 | 7,158 | 16,048 | 96,133 | 120,823 | 410,619 | 2341 | 2942 |
| Jeonnam | 87,152 | 75,627 | 63,301 | 48,397 | 7,032 | 55,429 | 500 | 8,409 | 20,640 | 118,730 | 148,279 | 457,481 | 2595 | 3241 |
| Jeju | 15,108 | 12,712 | 11,194 | 9,040 | 497 | 9,537 | 73 | 3,235 | 1,952 | 20,731 | 25,991 | 115,768 | 1791 | 2245 |

Note: Source: National health insurance service (2023), study on the establishment and operation of a jeonbuk-style stonefish system (2024).

3. Discussion

This study is an investigative research project conducted to assess the current status of elderly care service provision in a specific provincial region facing a super-aged society, aiming to

inform future elderly care policy systems. Systems for the elderly were initiated to “promote health and stabilize daily life in old age, and to alleviate the burden on their families, thereby improving the quality of life for citizens” through “physical activity or household support provided to elderly individuals who find it difficult to perform daily activities independently due to old age or age-related illnesses”[17][18][19][20][21][22].

South Korea secured its initial target service beneficiaries relatively quickly, and service users have demonstrated high satisfaction levels. Furthermore, the burden on family caregivers has been alleviated, and the system has significantly contributed to creating social jobs through infrastructure expansion, leading to a successful and stable establishment[23][24][25][26].

However, it is true that improvement tasks exist in various areas. Furthermore, experts commonly agree that the major problems with the long-term care insurance system can be broadly categorized into about four issues.

The issues include restrictions on coverage scope (beneficiary eligibility), declining quality of long-term care services, insufficient linkage between medical and long-term care, and the risk of financial insufficiency threatening sustainability[27][28].

Priority improvement tasks identified include enhancing service quality, strengthening care-medical coordination, improving the quality of related personnel, securing insurance fund stability, improving the grading assessment system, establishing a care management system, supporting informal caregivers such as family caregivers, and strengthening home-based services[29][30].

The 2024 plan for establishing and operating the Jeonbuk-style care system aims to build a care infrastructure capable of providing ongoing care for the growing elderly population[16]. It seeks to create a physical environment where care services can be accessed not only in care facilities but also in all areas within the home and community, and to ensure access to national care services. Jeonbuk-style care has established community care as a key policy direction, where relevant private institutions or organizations providing care services, along with administrative agencies, participate together to provide integrated care services. It is promoting the establishment of an integrated support system for care needs through continuous and systematic support by providing public-private participatory care services involving various care providers from private companies and state agencies, and offering integrated care services that link diverse local welfare resources[16].

Based on the survey findings, for the elderly, including those not eligible for long-term care grades, those not receiving long-term care benefits, dementia patients, and those living alone, home-visit medical care and care support, along with treatment and healing support for dementia patients and their families, are necessary to ensure a healthy later life.

Support is needed for elderly individuals with disabilities, those living alone, and those with dementia, consisting of integrated care services combining medical treatment and nursing care, along with temporary care and nursing services for acute patients after hospital discharge. Services for the elderly should consist of medical care such as medication guidance and home-visit customized exercise rehabilitation, daily living support, household assistance including house-keeping support, and facility care including temporary and short-term care.

Furthermore, to address safety concerns for the elderly and create a secure living environment while supporting stable community life, the primary support should include health counseling and daily living care.

4. Conclusion

Due to insufficient human and material infrastructure, it is true that over the past 15 years, our country has primarily focused on providing facility services for elderly individuals with severe functional disabilities and reducing the burden of care on their families to ensure stable establishment during the initial implementation phase. The direction we should pursue going forward is to strive to adhere more faithfully to the fundamental principles of long-term care protection. From the perspective of health and functionality, it is necessary to actively accommodate all individuals requiring public protective services to ensure accessibility and equity. The core objective of the services provided to these individuals should not be mere custodial care, but rather the enhancement of their independence and quality of life.

To properly achieve this purpose, all services provided must be consumer-centered and tailored to the health and functional level of each individual. Therefore, a rational, integrated assessment plan capable of appropriately evaluating each person's health status and functional level must be established and applied. Based on this assessment, individualized and appropriate care plans must be provided. It is desirable for integrated senior care support centers capable of properly carrying out these processes to be established within each local community. These centers should function as institutions where all community residents requiring public services can easily access health and functional level assessments and receive appropriate care plans. Particularly, to proactively address the increasing demand for long-term care alongside the ongoing aging trend and ensure the sustainable operation of the system, strengthening preventive services for health promotion and functional improvement through enhanced public-private partnerships for community-dwelling seniors is deemed the foremost task. Beyond simple care focused on protection and nursing, there is a need to reorganize the integrated care delivery system to comprehensively provide psychological and emotional support, cultural and leisure activities, and the formation of social networks. Strengthening the linkage between public and private care systems is necessary to drive the advancement and qualitative growth of care services.

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6. Appendix

6.1. Author's contribution

| | Initial name | Contribution |
|-----------------------|--------------|---|
| Lead Author | RH | -Set of concepts <input checked="" type="checkbox"/> -Design <input checked="" type="checkbox"/> -Getting results <input checked="" type="checkbox"/> -Analysis <input checked="" type="checkbox"/> -Make a significant contribution to collection <input checked="" type="checkbox"/> -Final approval of the paper <input checked="" type="checkbox"/> -Corresponding <input checked="" type="checkbox"/> -Play a decisive role in modification <input checked="" type="checkbox"/> |
| Corresponding Author* | ML | -Significant contributions to concepts, designs, practices, analysis and interpretation of data <input checked="" type="checkbox"/> -Participants in Drafting and Revising Papers <input checked="" type="checkbox"/> -Someone who can explain all aspects of the paper <input checked="" type="checkbox"/> |

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Publisher: J-INSTITUTE
ISSN: 2189-7603

Website: j-institute.org

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DOI Address:
dx.doi.org/10.22471/crisis.2025.10.0.35



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Safety Assessment and Occupational Protection Strategies for Paraphenylenediamine(PPD) Exposure in the Beauty Industry

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Abstract

Purpose: This study evaluates the toxicological hazards of paraphenylenediamine(PPD) to establish safety assessment protocols and occupational protection strategies for the beauty industry. PPD is internationally classified as a category 1A skin sensitizer, and particular attention is given to the safety risks associated with “black henna” products containing illegally high concentrations of PPD and misleading “natural” claims. By comparing international regulatory standards, this study aims to propose a risk-management framework to enhance protection for both beauty practitioners and consumers from preventable chemical hazards.

Method: A systematic literature review was conducted using international and domestic databases (PubMed, Scopus, ScienceDirect, KISS, and RISS) covering studies published between 2000 and 2024. Inclusion criteria focused on PPD-related toxicological mechanisms, chemical detection in black henna products, occupational contact dermatitis, and official safety regulations issued by the FDA, EU SCCS, and MFDS. Data were synthesized through structured thematic analysis across four safety domains: molecular toxicology, occupational and consumer exposure risks, regulatory frameworks, and evidence-based safety management strategies.

Results: PPD was found to be associated with acute and chronic contact dermatitis, pigmentary disorders, and severe systemic toxicities, including methemoglobinemia. Epidemiological evidence indicates that approximately 20-30% of Korean hairdressers experience hair dye-related dermatologic symptoms, with sensitization rates increasing with employment duration. Investigations by the Korea Consumer Agency reported that products misleadingly labeled as “chemical-free” contained up to 1.0% PPD and levels of microbial contamination exceeding safety standards by as much as 11,000-fold. Comparative regulatory analysis further showed that the EU Scientific Committee on Consumer Safety (SCCS) enforces the strictest controls, limiting the final concentration of PPD in hair dyes to $\leq 2\%$ and prohibiting its use in temporary skin tattoos.

Conclusion: PPD represents a high-risk allergenic chemical associated with significant occupational and consumer exposure concerns. Strengthening domestic safety management requires the implementation of mandatory patch testing, enhanced ingredient labeling and regulatory enforcement, improved ventilation and use of personal protective equipment, and the continued development and adoption of safer alternatives to PPD.

Keywords: Paraphenylenediamine(PPD), Black Henna, Hair Dye Safety, Allergic Sensitizer, Cosmetic Safety

1. Introduction

1.1. Research background

Hair dyes are among the most frequently used cosmetic chemical products in modern beauty salons, with millions of consumers applying them regularly worldwide. Among various dye precursors, paraphenylenediamine(PPD) is a key oxidative dye ingredient because of its strong coloring intensity, superior gray coverage, and long-lasting performance[1]. PPD readily undergoes oxidation in the presence of hydrogen peroxide, forming dark chromophores that permanently

bind to the hair cortex, which explains its widespread use in both professional salon products and home-use hair dyes[2].

However, the extensive and repeated use of oxidative hair dyes has raised growing concerns regarding occupational and public health safety. Unlike many cosmetic substances intended for superficial or transient contact, hair dyes are applied directly to the scalp and hair fibers for prolonged periods, increasing the likelihood of dermal absorption and systemic exposure. Importantly, PPD is not merely a cosmetic colorant but an aromatic amine, a chemical class historically associated with allergic sensitization and hematotoxic effects[2][3]. Consequently, international toxicological and clinical studies have consistently reported adverse health outcomes associated with PPD exposure, particularly among hairdressers and frequent users of hair dye products[4][5][6].

In recent years, increasing consumer demand for darker shades and rapid coloring outcomes has further expanded the use of PPD beyond conventional oxidative hair dyes. Notably, PPD has been widely detected in commercially distributed “black henna” products, which are often misleadingly marketed as natural alternatives[7][8]. Traditional henna (*Lawsonia inermis*) produces only reddish-brown pigmentation and does not contain PPD; however, many black henna formulations incorporate high concentrations of PPD (typically 3–15%) to achieve dark, tattoo-like coloration. These products are frequently used during cultural events, cosmetic treatments, or do-it-yourself procedures, thereby increasing the risk of unintended sensitization, particularly among young or first-time users[9].

Beyond the clinical risks, it is critical to analyze the underlying regulatory philosophies that govern PPD use. While the EU SCCS operates under the ‘Precautionary Principle,’ strictly limiting PPD concentrations to ensure a high margin of safety, other regions may lean toward ‘Market Surveillance’ models that focus more on post-market compliance. In South Korea, the current ‘Command and Control’ system based on MFDS notifications ensures legal compliance but may face limitations in addressing the practical complexities of salon environments and illegal distribution channels. Therefore, this study seeks to re-evaluate these regulatory frameworks to propose a more context-specific safety governance for the domestic beauty industry. From an occupational health perspective, hairdressers represent one of the highest-risk professional groups for chemical-induced contact dermatitis due to their repeated and cumulative exposure to PPD-containing products, often in environments with insufficient ventilation or inconsistent use of personal protective equipment. Epidemiological studies indicate that approximately 20–30% of Korean hairdressers experience dye-related skin symptoms, with sensitization rates increasing in proportion to years of employment[4][5][6]. These findings suggest that PPD-related health risks are not isolated clinical events but constitute an emerging public health issue requiring systematic evaluation.

International regulatory bodies have responded to these concerns by strengthening safety management measures. In particular, the European Union Scientific Committee on Consumer Safety (SCCS) has restricted the maximum allowable concentration of PPD in oxidative hair dyes and strictly prohibited its direct-to-skin application in temporary tattoo products[10]. In contrast, regulatory enforcement in many Asian markets, including Korea, remains largely focused on labeling compliance, leaving substantial gaps in monitoring illegal distribution, mislabeling practices, and occupational exposure control. These discrepancies highlight the need for a more comprehensive scientific and regulatory reassessment of PPD use in the beauty industry.

1.2. Problem statement

PPD is globally classified as a strong skin sensitizer, capable of inducing allergic contact dermatitis even after a single exposure [2][3]. Repeated or prolonged exposure has been associated

with chronic dermatitis, pigmentary disorders, respiratory symptoms, facial edema, and, in severe cases, systemic toxicity such as methemoglobinemia[10][11]. Despite increasing consumer interest in “natural” cosmetic products, many commercially available black henna formulations continue to contain high concentrations of PPD (3–15%) to achieve darker coloration, posing substantial safety risks[7]. These products are frequently marketed using claims such as “natural” or “chemical-free,” which may mislead consumers and undermine informed risk perception[9].

Domestic exposure risks are also significant. Studies have reported that 20–30% of Korean hairdressers experience skin disorders related to hair dye use [4]. Moreover, regulatory inspections have revealed that certain products labeled as “chemical-free” contained detectable levels of PPD, and some exceeded microbial safety limits by more than 11,000-fold, exposing structural vulnerabilities within Korea’s product safety management system [12].

1.3. Necessity of the study

Given the extensive use of PPD in both professional and consumer hair dye products and the increasing incidence of dye-related allergic disorders, a comprehensive reassessment of its toxicological mechanisms and real-world exposure risks is warranted. Hairdressers are subjected to frequent and prolonged exposure through daily occupational practices, significantly increasing the likelihood of sensitization and chronic dermatologic conditions. Meanwhile, general consumers—often lacking sufficient safety information—may unknowingly experience hazardous exposure, particularly through mislabeled or illegally distributed products.

Although previous studies have documented the allergenic and systemic risks associated with PPD, regulatory and safety management practices in several regions, including Korea, remain largely reactive and centered on ingredient labeling compliance. Such approaches have proven insufficient to address illegal product circulation, underreporting of adverse reactions, and misuse in black henna applications[13]. In contrast, the EU SCCS has classified PPD as a Sensitizer Category 1A substance and imposed strict concentration limits ($\leq 2\%$) alongside prohibitions on direct skin application, representing one of the most advanced global safety standards[10].

1.4. Limitations of previous studies

Despite a growing body of literature on PPD toxicity, existing studies exhibit several limitations. Most investigations focus either on mechanistic toxicology or isolated clinical case reports, without integrating molecular sensitization pathways with real-world exposure scenarios in beauty salon environments. In addition, relatively few studies have systematically examined the misuse of high-concentration PPD in commercial black henna products or the implications of misleading marketing claims. Comparative regulatory analyses are also limited, as many studies review single-country policies without conducting cross-national evaluations among regions with differing enforcement levels.

Furthermore, limited attention has been paid to translating toxicological evidence into practical safety management strategies tailored to beauty professionals. Structured integrative frameworks—such as Structured Literature Reviews (SLRs)—that synthesize toxicology, exposure assessment, regulatory analysis, and policy recommendations remain scarce.

1.5. Research purpose

The purpose of this study is to systematically evaluate the toxicological properties and potential health risks of paraphenylenediamine(PPD) used in beauty salons by integrating scientific literature, clinical evidence, and regulatory documentation. Specifically, this study

aims to: (1) analyze the chemical characteristics and toxicological mechanisms of PPD; (2) investigate misuse patterns, including high-concentration PPD in commercial black henna products; (3) assess occupational and consumer exposure risks; and (4) conduct a comparative review of international regulatory standards in the EU, the United States, and Korea.

Ultimately, this study seeks to propose evidence-based safety management strategies to protect both beauty practitioners and general consumers from PPD-related hazards.

2. Main Body

2.1. Methods

This study employed a Structured Literature Review (SLR) framework integrated with toxicological evidence mapping to comprehensively evaluate the health hazards associated with Paraphenylenediamine (PPD) in professional beauty environments. The methodological procedure comprised four sequential phases: research scope formulation, literature identification, eligibility screening, and structured data synthesis.

First, the research scope was defined using the PICO criteria (Population, Intervention, Comparison, Outcome) to ensure a systematic and unbiased approach to data extraction. The target population included beauty practitioners and consumers exposed to oxidative hair dyes, while the intervention component focused specifically on PPD exposure and misuse scenarios such as high-concentration black henna applications. Comparison parameters encompassed regulatory concentration limits and alternative dye precursors. The primary outcomes centered on dermatologic and systemic toxicities associated with PPD.

Second, a comprehensive literature search was conducted across major international scientific databases—PubMed, Scopus, Web of Science, and ScienceDirect—and supplemented with Korean academic platforms such as KISS and RISS to incorporate domestic regulatory and exposure information. Search strategies combined relevant keywords, including “Paraphenylenediamine,” “PPD,” “hair dye toxicity,” “occupational exposure,” “black henna,” and “contact dermatitis.” Only peer-reviewed articles and authoritative documents published in English or Korean from 2000 to 2025 were included to reflect contemporary scientific and regulatory developments. The comparative analysis focused on three specific criteria: (1) maximum allowable concentration of PPD, (2) restricted application areas (e.g., tattoos), and (3) mandatory labeling requirements across EU, US, and Korean regulatory frameworks.

Third, eligibility screening followed PRISMA-aligned filtering procedures. Records were initially evaluated by title and abstract, followed by full-text review to eliminate duplicates, methodologically weak studies, non-toxicological reports, and speculative commentaries. Regulatory documents issued by the Scientific Committee on Consumer Safety (SCCS) and the U.S. Food and Drug Administration were incorporated to support comparative regulatory and policy analysis.

Fourth, all eligible studies were systematically coded and classified into four analytic dimensions: (1) chemical and toxicological characteristics of PPD, (2) occupational and consumer exposure pathways, (3) misuse patterns, including high-concentration PPD in commercial black henna, and (4) international regulatory risk-management strategies. To ensure methodological transparency and reproducibility, the comparative analysis of regulatory frameworks was structured around three core criteria: (1) the maximum allowable concentration of PPD in final products, (2) specific restrictions on application areas (such as the prohibition of use in temporary tattoos), and (3) mandatory labeling and safety warning requirements across the EU SCCS, U.S. FDA, and Korean MFDS systems. Qualitative findings were thematically analyzed to identify recurring hazard patterns, while quantitative data—such as

exposure frequency, sensitization prevalence, and regulatory concentration limits—were tabulated to facilitate comparative interpretation. Moreover, case reports documenting severe allergic reactions were separately examined to underscore their clinical and real-world significance.

Through this integrated methodology, the study achieved a holistic, evidence-driven evaluation of PPD-related health hazards, ensuring that its conclusions are grounded in validated toxicological evidence, empirical field observations, and internationally recognized regulatory frameworks.

2.2. Results

2.2.1. Toxicological hazards and systemic risks of PPD

PPD is recognized as one of the most commonly identified contact sensitizers derived from hair dyes worldwide[2]. According to patch test-based clinical studies conducted both domestically and internationally, exposure to PPD has been shown to induce a wide spectrum of allergic contact dermatitis reactions, ranging from localized scalp or skin eczema to generalized dermatitis, urticaria and angioedema, respiratory symptoms, and, in rare cases, severe systemic toxicity[3].

In particular, a retrospective analysis of 105 patients with patch test-confirmed hair dye allergy demonstrated that higher frequency and longer duration of dye use were positively associated with broader areas of dermatitis involvement. Many patients exhibited periorbital dermatitis, generalized eczema, or urticaria-like eruptions[1].

Furthermore, in immunologically sensitized individuals, even brief skin contact with PPD can trigger immediate-type hypersensitivity reactions, which may progress to angioedema, airway compromise, or systemic dermatitis, as documented in multiple clinical case reports[10].

In addition, concerns regarding the long-term safety of PPD persist because of its potential genotoxic effects, including DNA damage, increased oxidative stress, and possible carcinogenicity[14].

Table 1. Clinical toxicology cases related to PPD exposure.

| Category | Study population / case characteristics | Major clinical symptoms | Patch test results | References |
|----------------------------------|---|---|---|------------|
| General clinic population | Patients with non-specific skin disorders | Contact dermatitis, erythema, pruritus | 4-7% positive | [2][3] |
| Suspected hair dye-related cases | Individuals presenting after hair dye use | Scalp, facial, neck eczema; swelling | 60-70% positive | [1] |
| Severe overexposure cases | Black henna users; high PPD exposure | Bullous dermatitis, burning sensation | Mostly positive | [3][10] |
| Occupational exposure group | Beauty practitioners with repeated exposure | Hand eczema, fissures, chronic dermatitis | Increased positivity with employment duration | [1][2] |

Note: Reported concentrations represent summarized averages from published studies and may vary depending on country and product type.

2.2.2. Misuse of high-concentration PPD in commercial black henna products

High concentrations of PPD, originally intended for use in oxidative hair dyes, have been increasingly identified in certain commercially distributed black henna products. Chemical analyses of unauthorized formulations have reported PPD levels ranging from 0.4% to as high as 29.5%, far exceeding the EU SCCS regulatory threshold of $\leq 2\%$ in final-use concentrations[7][10]. These levels constitute more than a tenfold breach of internationally accepted safety limits[10].

Manufacturers of black henna frequently adulterate products with PPD to achieve darker and more rapid coloration, despite the substance not being a natural component of *Lawsonia inermis* henna. This illicit practice substantially elevates the sensitization risk for first-time users and significantly exacerbates both acute and chronic allergic responses among individuals already sensitized to PPD, including beauty practitioners who experience repeated occupational exposure[8].

Furthermore, several black henna products have been misleadingly marketed as “natural,” “non-toxic,” or “chemical-free,” despite containing high concentrations of PPD. Comparative investigations have demonstrated a pronounced discrepancy between product labeling and actual chemical composition, confirming the presence of undeclared PPD and other synthetic additives[8][9]. This misinformation undermines consumer protection and hampers effective regulatory enforcement.

Taken together, the illegal incorporation of high-concentration PPD into black henna products creates a dual-risk structure: (1) heightened sensitization risk for general consumers upon initial exposure, and (2) increased occupational hazards for beauty professionals due to repeated cumulative exposure.

These findings underscore the urgent need for strengthened surveillance, accurate product labeling, and regulatory intervention to mitigate public health risks associated with black henna adulteration[8].

Table 2. Regulatory limits for PPD and measured concentrations in “black henna” products.

| Category | Regulatory characteristics | Permitted / detected PPD concentration | References |
|---|---|--|------------|
| EU SCCS (oxidative hair dyes) | Restriction on final use concentration | $\leq 2\%$ | [10] |
| Traditional henna (<i>Lawsonia inermis</i>) | No PPD content | 0% | [8] |
| Commercial black henna (foreign distribution) | Unregulated distribution; cases of illegal adulteration | 0.4–29.5% | [7][9] |

Note: Reported concentrations represent summarized averages from published studies and may vary depending on country and product type.

2.2.3. Vulnerabilities in domestic hair dye use and PPD management

In South Korea, beauty professionals are classified as a high-risk group for occupational exposure to PPD due to the nature of their work, which typically involves prolonged wet-work conditions, repeated hair dyeing procedures, and frequent non-use of protective equipment. Epidemiological data indicate that approximately 20–30% of hairdressers have experienced hair dye-related dermatologic disorders, and the incidence of contact dermatitis increases with longer years of employment[4].

Meanwhile, ingredient labeling and safety management for commercially distributed hair

dyes and henna products remain insufficient. An analysis by the Korea Consumer Agency of 30 permanent hair dye products revealed that 29 contained PPD within a range of 0.3–3.9%, which met the legal concentration limits but also demonstrated the widespread use of a high-risk allergen[12]. This finding underscores that compliance with concentration standards alone does not guarantee actual consumer safety.

Furthermore, repeated issues have been reported in the case of black henna and henna products, including.

- omission of full ingredient disclosure,
- refusal to provide documentation upon request,
- misleading claims such as “natural” or “chemical-free,” and
- regulatory blind spots pertaining to pigments used for tattooing, all of which contribute to persistent safety concerns[7][8][9].

Some products fraudulently labeled as “natural henna” were found to contain illegally added PPD, significantly increasing the likelihood of consumer misunderstanding.

Overall, PPD management in South Korea tends to focus narrowly on concentration thresholds, while failing to establish a comprehensive framework necessary for actual safety assurance. Critical gaps remain in (1) accurate ingredient disclosure, (2) improvement of advertising and labeling regulations, and (3) stronger oversight of non-cosmetic dyes, including tattoo pigments.

Therefore, a shift is required from limited concentration-based regulation toward a full life-cycle risk management system—spanning ingredient transparency, product labeling, and area-specific usage controls—to ensure the safety of both consumers and beauty professionals.

2.2.4. Preliminary evaluation of PPD substitutes and safer alternatives

The EU SCCS classifies PPD as a Sensitizer Category 1A substance and implements strict preventive regulatory measures, including limiting its final-use concentration in oxidative hair dyes to $\leq 2\%$ and prohibiting its application in temporary tattoos involving direct skin contact[10]. These measures exemplify a proactive and precautionary framework for consumer chemical safety.

In contrast, domestic management practices rely predominantly on post-market monitoring centered on labeling compliance, a system that presents inherent limitations in preventing the circulation of high-concentration adulterated products and in ensuring effective consumer protection. This regulatory divergence highlights a substantial safety gap between international standards and current domestic oversight, underscoring the need for Korea to transition toward a more proactive, risk-based regulatory framework[13].

Concurrently, recent studies have investigated the development of alternative dye precursors and pigment systems designed to reduce the sensitization risks associated with aromatic amines such as PPD and to enhance long-term safety. For example, non-PPD oxidative dye systems and disperse dye-based pigments (e.g., Disperse Yellow 9) have been proposed as candidate substances with comparatively lower sensitization potential, and early findings indicate a reduced incidence of contact allergy[15][16][17].

However, the current evidence base for these alternatives remains limited, particularly regarding their toxicological profiles, long-term safety assessments, and standardized patch-test data. Consequently, additional comprehensive and systematic research is required before these candidate substances can be recommended as reliable, full-scale substitutes for PPD.

Collectively, the results highlight that PPD poses not only immediate sensitization risks but also potential long-term toxicological concerns[18].

Accordingly, the following discussion examines the broader implications of these findings for safety management and regulatory policy.

2.3. Discussion

2.3.1. Reaffirmation of PPD’s hazard profile

The findings of this study reaffirm that p-phenylenediamine (PPD) presents substantial toxicological risks that extend well beyond simple irritant reactions. Accumulated evidence demonstrates that PPD functions as a potent skin sensitizer capable of eliciting acute cutaneous manifestations as well as severe systemic responses[11][19]. under certain exposure conditions. Clinical patch-test investigations consistently identify exposure to PPD-containing hair dyes as a major contributor to allergic contact dermatitis[1][2][3].

In one clinical study involving hair-dye users, more than half of the participants (54 out of 80) exhibited a positive PPD patch-test response[20]. Reported symptoms ranged from localized scalp or facial dermatitis to widespread eczema, with some cases progressing to urticaria, angioedema, and respiratory involvement[3][9].

These findings indicate that PPD should not be regarded as a mild cosmetic irritant, but rather as a high-risk chemical with strong sensitizing properties, as repeatedly demonstrated across clinical and epidemiologic studies[4][9][11]. In sensitized individuals, even trace-level exposure may provoke immediate systemic allergic reactions, including angioedema and respiratory symptoms[11][12]. In addition to these immunologic effects, emerging toxicological evidence suggests potential genotoxicity associated with PPD, underscoring growing concerns regarding its long-term health implications[18].

Concerns regarding systemic toxicity have further intensified in recent years. A 2023 systematic review identified PPD and related oxidative dye intermediates as exhibiting genotoxic potential, indicating that chronic or repeated exposure may pose additional health risks beyond cutaneous sensitization[18].

Occupational exposure patterns further reinforce this hazard profile. Beauty practitioners—who experience repeated and often unavoidable skin contact during routine dyeing procedures—exhibit significantly elevated rates of sensitization and dermatitis over time[4][5][6].

Taken together, these multidimensional hazards—including acute dermatitis, systemic hypersensitivity reactions, and potential genotoxicity—demonstrate that continued reliance on PPD-based hair dyes constitutes a significant public health concern. Accordingly, strengthened regulatory oversight and enhanced risk-management strategies are essential to safeguard the health and safety of both beauty professionals and general consumers.

2.3.2. Occupational exposure and domestic safety gaps

The occupational exposure of hairdressers to PPD-containing hair dyes constitutes a major health concern worldwide, including Korea. Previous epidemiological and occupational dermatology studies have reported that a substantial proportion of hairdressers experience skin problems consistent with occupational contact dermatitis, with prevalence increasing in relation to cumulative exposure and years of employment[7][21][22]. These conditions commonly affect the hands and are associated with frequent wet work and repeated dye application in the absence of adequate protective measures. This high prevalence suggests limitations in current workplace safety practices, including inconsistent glove use and

insufficient ventilation or skin-care protocols. In addition, regulatory guidance and formal safety education for salon professionals remain largely voluntary, potentially exacerbating occupational risk under repeated exposure.

Moreover, market surveillance and product-analysis studies have revealed systemic weaknesses in domestic safety oversight. A recent Korean analysis of 28 commercially available oxidative hair dyes found detectable levels of PPD and other sensitizing agents, including some formulations whose labelling did not reflect these contents accurately — indicating possible mislabeling or insufficient ingredient disclosure[12]. Such findings raise serious concerns about the integrity of cosmetic product regulation and the effectiveness of post-market monitoring in ensuring consumer and worker safety.

When these factors — frequent occupational exposure + regulatory gaps + product mis- or under-labeling — converge, the resultant risk environment for hairdressers and general consumers becomes significantly elevated. In practice, many workers may be unknowingly exposed to hazard levels considerably above safe thresholds, especially in contexts lacking strict safety measures or oversight.

2.3.3. Bridging the gap with international standards

The comparison between regulatory regimes under the Scientific Committee on Consumer Safety (SCCS, EU) framework and current Korean regulatory practices reveals significant discrepancies that may undermine both consumer and worker safety. Under EU regulations, PPD and its salts are strictly controlled; when used in oxidative hair dyes, the final post-mixing “on-head” concentration of PPD must not exceed 2% (free base)[10]. In addition, the use of PPD-containing products for direct-to-skin applications—such as temporary “black henna” tattoos and eyelash or eyebrow dyes—is either severely restricted or prohibited[10].

By contrast, regulatory systems in many East Asian markets, including Korea, continue to rely predominantly on ingredient labeling compliance, without enforceable limits on PPD concentration in final-use products or sufficiently robust mechanisms for monitoring misuse (e.g., black henna, semi-permanent dyes, or unregulated imports)[13]. As a result, PPD-containing products with potentially unsafe exposure levels may circulate in the market, leaving both consumers and salon professionals vulnerable to preventable health risks.

Bridging this regulatory gap would require several key measures. First, EU-level concentration limits for oxidative hair dyes ($\leq 2\%$ PPD free base after mixing) should be adopted and enforced for both domestically manufactured and imported products. Second, direct-to-skin applications involving PPD-containing dyes—including temporary henna tattoos and eyebrow or eyelash dyes—should be explicitly prohibited in line with the EU model. Third, mandatory labeling standards and pre-market safety assessments should be instituted, complemented by systematic post-market surveillance and periodic safety audits. In parallel, occupational safety guidelines for salon professionals should be strengthened through enforceable requirements for adequate ventilation, compulsory use of protective gloves and barrier measures, and standardized training on chemical hazards. Finally, consumer education initiatives, including clear guidance on pre-use patch testing, are essential to reduce the incidence of first-time sensitization.

Given the robust and consistent evidence regarding the sensitization potential of PPD, regulatory reforms along these lines are not merely precautionary but are scientifically justified and urgently required to ensure effective public health protection.

2.3.4. Policy implications and safety recommendations

The evidence synthesized in this review highlights an urgent need to strengthen national policy frameworks to protect both salon professionals and consumers from PPD-related health

hazards. Drawing on toxicological findings, regulatory comparisons, and occupational exposure data, four key policy recommendations are proposed as priorities for domestic safety improvement. First, mandatory pre-use patch testing and standardized consumer guidance should be implemented. Regulatory authorities increasingly recommend patch testing prior to exposure to cosmetic colorants containing strong sensitizers such as PPD[21][22][23][24][25]. Clear warnings and explicit instructions can significantly reduce the incidence of initial sensitization-related adverse events, especially considering the high prevalence of PPD allergy reported in consumer epidemiological data[26], and its potential for genotoxic damage[27][28]. Second, ingredient labeling requirements should be reinforced through the adoption of standardized warning phrases and stricter enforcement mechanisms. As consumers rely heavily on product labels to make informed health decisions, improved transparency regarding chemical hazards is essential. Regulatory action against misleading claims such as “chemical-free” or “natural” should be strengthened, with meaningful penalties imposed for non-compliance to ensure accurate ingredient disclosure[24]. Such labeling standards should be consistent with international risk assessment guidelines for skin sensitizers to ensure global safety alignment[29]. Third, occupational exposure controls should be enhanced through improved salon ventilation and the compulsory use of personal protective equipment, particularly protective gloves. Inhalation and dermal exposure to hair-dye chemicals are well-documented occupational risks, and appropriate ventilation systems and PPE have been shown to substantially reduce these hazards[8][11]. Finally, the development and adoption of safer alternative ingredients should be actively encouraged as part of cosmetic formulation strategies. Toxicologically safer substitutes for high-risk chemicals such as PPD should be systematically evaluated and prioritized to minimize long-term health risks[12][25][28][30]. This includes continued investigation into low-sensitization pigments and alternative dye systems, as identifying viable oxidative intermediates is crucial for reducing cross-reactivity[28]. Furthermore, recent reviews of cosmetic ingredients emphasize that a transition toward bio-based or technologically modified low-toxicity alternatives is essential for the sustainable safety of the hair dye industry[30].

In conclusion, these integrated measures establish a strategic policy framework for proactive, evidence-based protection. By aligning domestic safety protocols with international regulatory standards and evolving scientific evidence, this pathway ensures the long-term welfare of both consumers and occupational professionals.

3. Conclusion

3.1. Research summary

This study analyzed the toxicological hazards of Paraphenylenediamine(PPD), a primary oxidative dye ingredient used in hair coloring products, and evaluated the current status of domestic and international safety management systems. The findings reaffirm that PPD is a strong sensitizer capable of inducing allergic contact dermatitis even after a single exposure and, in severe cases, may result in systemic toxicities such as methemoglobinemia. Market investigations revealed that many commercial black henna products contained high concentrations of PPD (3–15%) and were often falsely labeled as “natural” or “chemical-free,” posing significant risks to consumer health.

In Korea, 20–30% of hairdressers reported dye-related dermatologic symptoms, and several products labeled as “chemical-free” were found to contain PPD or microbial levels exceeding safety limits by up to 11,000-fold, demonstrating substantial weaknesses in the current safety oversight system. International regulatory comparisons further confirmed that the European Union (EU SCCS) applies the strictest standards by classifying PPD as a Category 1A sensitizer

and limiting its final use concentration to 2%. Additionally, the study conducted preliminary safety testing of a potential PPD alternative, Carthamus tinctorius pigment, through HPLC analysis and a 48-hour clinical patch test involving 20 female participants.

3.2. Policy and industrial recommendations

Based on the confirmed hazards of PPD and the identified gaps in domestic safety management, the following key recommendations are proposed:

1) Strengthen regulatory standards: Align national regulations with EU SCCS criteria, including limiting final PPD concentrations in cosmetic products to 2% or less[10].

2) Mandatory patch testing: Require patch testing prior to the use of PPD-containing hair dyes and strengthen consumer notification regarding health risks[21][22][23].

3) Enhanced labeling and enforcement: Improve ingredient labeling accuracy and intensify surveillance and penalties for falsely labeled products marketed as “natural” or “chemical-free”[24].

4) Workplace safety improvements: Mandate adequate ventilation systems and the use of protective equipment (e.g., gloves) in hair salons to reduce occupational exposure[4][5][6][8][11].

5) Support development of safer alternatives: Promote the research, development, and commercialization of safer dye substitutes—such as Carthamus tinctorius pigment—to reduce dependence on PPD in the beauty industry[12][25][28][30].

3.3. Study limitations

This study relied primarily on a structured literature review (SLR), and therefore its conclusions are inherently limited by the scope and quality of available literature. The preliminary safety assessment of the proposed PPD substitute involved a small sample (20 female participants) and a short exposure period (48 hours), limiting generalizability. Moreover, quantitative HPLC data and detailed dermatological scoring results for the substitute pigment were not available in the source material, restricting the extent to which definitive conclusions can be drawn regarding long-term safety and efficacy compared with PPD.

3.4. Future research directions

Future studies should:

- 1) Conduct large-scale, long-term clinical evaluations of PPD substitute ingredients to assess both safety and performance (color intensity, durability).
- 2) Perform quantitative exposure analyses measuring airborne and dermal concentrations of PPD in real salon environments to better assess occupational risk.
- 3) Examine the effectiveness of strengthened regulations by monitoring post-implementation compliance rates and reductions in health risks among beauty workers and consumers.

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5. Appendix

5.1. Author's contribution

| Initial name | Contribution |
|--------------|--|
| Author YL | <ul style="list-style-type: none"> -Set of concepts <input checked="" type="checkbox"/> -Design <input checked="" type="checkbox"/> -Getting results <input checked="" type="checkbox"/> -Analysis <input checked="" type="checkbox"/> -Make a significant contribution to collection <input checked="" type="checkbox"/> -Final approval of the paper <input checked="" type="checkbox"/> -Corresponding <input checked="" type="checkbox"/> -Play a decisive role in modification <input checked="" type="checkbox"/> -Significant contributions to concepts, designs, practices, analysis and interpretation of data <input checked="" type="checkbox"/> -Participants in Drafting and Revising Papers <input checked="" type="checkbox"/> -Someone who can explain all aspects of the paper <input checked="" type="checkbox"/> |

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