**Élaboration de démonstrateurs d’attaques Web : OWASP Top 10 Vulnerabilities (2021)**

**Development of Web Attack Demonstrators : OWASP Top 10 Vulnerabilities (2021)**

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# Project abstract

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(typically 150-250 words)

## summary and objectives of the project

Every year, web servers experience attacks with various consequences: data theft, server downtime, identity theft, etc., leading to financial losses and damage to the company's reputation. The OWASP Foundation regularly publishes the Top Ten, which is a ranking of the 10 most critical vulnerabilities for web applications.

This project aims to study the vulnerabilities highlighted in the latest Top Ten (from 2021) and to implement a number of demonstrators to illustrate the exploitation of certain vulnerabilities through attacks on real-world web applications.





Two deliverables are expected:

— A set of demonstrators

— A set of explanatory documents

## Methodology

The key steps are:

* understand the attack concept (threats and vulnerabilities)
* propose an implementation (recent environment, remote operation
* propose a fix for the vulnerability to render the attack ineffective

## key findings

**Table of contents**

[1 Project abstract 2](#_Toc180620344)

[1.1 summary and objectives of the project 2](#_Toc180620345)

[1.2 Methodology 3](#_Toc180620346)

[1.3 key findings 3](#_Toc180620347)

[2 Introduction 7](#_Toc180620348)

[3 Literature Review 7](#_Toc180620349)

[4 Methodology 7](#_Toc180620350)

[5 Mitigation 8](#_Toc180620351)

[5.1 Use Framework Security Features 8](#_Toc180620352)

[5.2 Regular Security Audits and Testing 8](#_Toc180620353)

[6 Vulnerabilities study 9](#_Toc180620354)

[6.1 Broken Access Control 9](#_Toc180620355)

[6.1.1 Description 9](#_Toc180620356)

[6.1.2 Occurrence 9](#_Toc180620357)

[6.1.3 Risk Measure 9](#_Toc180620358)

[6.1.4 Implementation example 9](#_Toc180620359)

[6.2 Cryptographic Failures 9](#_Toc180620360)

[6.2.1 Description 9](#_Toc180620361)

[6.2.2 Occurrence 10](#_Toc180620362)

[6.2.3 Risk Measure 10](#_Toc180620363)

[6.2.4 Implementation example 10](#_Toc180620364)

[6.3 Injection 10](#_Toc180620365)

[6.3.1 Description 10](#_Toc180620366)

[6.3.2 Occurrence 10](#_Toc180620367)

[6.3.3 Risk Measure 10](#_Toc180620368)

[6.3.4 Implementation example 10](#_Toc180620369)

[6.3.5 Mitigation Strategies 12](#_Toc180620370)

[**6.4** Insecure Design 14](#_Toc180620371)

[6.4.1 Description 14](#_Toc180620372)

[6.4.2 Occurrence 15](#_Toc180620373)

[6.4.3 Risk Measure 15](#_Toc180620374)

[6.4.4 Implementation example 15](#_Toc180620375)

[6.5 Security Misconfiguration 15](#_Toc180620376)

[6.5.1 Description 15](#_Toc180620377)

[6.5.2 Occurrence 15](#_Toc180620378)

[6.5.3 Risk Measure 15](#_Toc180620379)

[6.5.4 Implementation example 15](#_Toc180620380)

[6.6 Vulnerable and Outdated Components 16](#_Toc180620381)

[6.6.1 Description 16](#_Toc180620382)

[6.6.2 Occurrence 16](#_Toc180620383)

[6.6.3 Risk Measure 16](#_Toc180620384)

[6.6.4 Implementation example 16](#_Toc180620385)

[6.7 Identification and Authentication Failures 17](#_Toc180620386)

[6.7.1 Description 17](#_Toc180620387)

[6.7.2 Occurrence 17](#_Toc180620388)

[6.7.3 Risk Measure 17](#_Toc180620389)

[6.7.4 Implementation example 17](#_Toc180620390)

[6.8 Software and Data Integrity Failures 17](#_Toc180620391)

[6.8.1 Description 17](#_Toc180620392)

[6.8.2 Occurrence 18](#_Toc180620393)

[6.8.3 Risk Measure 18](#_Toc180620394)

[6.8.4 Implementation example 18](#_Toc180620395)

[6.9 Security Logging and Monitoring Failures 18](#_Toc180620396)

[6.9.1 Description 18](#_Toc180620397)

[6.9.2 Occurrence 18](#_Toc180620398)

[6.9.3 Risk Measure 18](#_Toc180620399)

[6.9.4 Implementation example 19](#_Toc180620400)

[6.10 Server-Side Request Forgery (SSRF) 19](#_Toc180620401)

[6.10.1 Description 19](#_Toc180620402)

[6.10.2 Occurrence 19](#_Toc180620403)

[6.10.3 Risk Measure 19](#_Toc180620404)

[6.10.4 Implementation example 19](#_Toc180620405)

[7 Discussion 21](#_Toc180620406)

[8 Conclusion 21](#_Toc180620407)

[9 References 21](#_Toc180620408)

[10 Appendices 23](#_Toc180620409)

[11 Acknowledgments 23](#_Toc180620410)

[12 Executive Summary 23](#_Toc180620411)

# Introduction

* Background information on the topic.
* Purpose and objectives of the project.
* Scope of the report.
* Significance of the study.

# Literature Review

* Summary of existing research and literature related to the project.
* Identification of gaps in knowledge that your project addresses.

# Methodology

* understand the the attack concept (threats and vulnerabilities) through documentation:
  + OWASP 2021 : Website: [owasp.org](https://owasp.org)
  + PortSwigger. (2021). Burp Suite Documentation. Available at: https://portswigger.net/burp/documentation
* propose an implementation (recent environment, remote operation
  + **Use a Controlled Environment** :Set up a local environment and/or use a virtual machine to host 2 websites:
    - the vulnerable web application (ensure it’s not exposing real users or systems to risk)
    - The corrected version mitigating the vulnerabilities
  + **Choose and install deveplopement tools :**
    - HTML, PHP, Javascript, MySQL, Apache
    - Github for versionning and collaboration
  + **Development of the applications components**
    - First the vulnerable web application
    - Second, propose a fix for each studied vulnerability to render the attacks ineffective
  + **Tests:**

Use tools to help identify vulnerabilities and mitigate them:

* + - **Burp Suite**: A powerful web vulnerability scanner.
    - **OWASP ZAP**: An open-source web application security scanner.
* Document:

Keep a record of the studied vulnerabilities, how to exploit them, and potential remediation steps.

# Mitigation

Describe general methods and guidance for mitigating vulnerabilities.

Specific and detailed ones are described in the vulnerabilities study.

## Use Framework Security Features

* **Purpose**: Leverage built-in security features provided by web frameworks.
* **Implementation**:
  + Many modern frameworks (e.g., React, Angular, Vue) automatically escape output or provide security features to help mitigate XSS risks.
  + Review your framework’s documentation for recommended practices.

## Regular Security Audits and Testing

* **Purpose**: Identify and fix vulnerabilities before they can be exploited.
* **Implementation**:
  + Conduct regular security audits of your codebase to find potential XSS vulnerabilities.
  + Use automated security testing tools (like OWASP ZAP or Burp Suite) to scan for vulnerabilities.
  + Implement manual code reviews focusing on input handling and output rendering.

# Vulnerabilities study

## Broken Access Control

### Description

Broken access control occurs when users can act outside their intended permissions, allowing unauthorized actions.

### Occurrence

Commonly found in web applications where user roles are poorly defined or enforced.

### Risk Measure

Risk Level: High. Exploitation can lead to data breaches, unauthorized data manipulation, and complete system compromise.

### Implementation example

#### Easy Detection:

* + Attempt to access a restricted resource (e.g., admin dashboard) by manipulating the URL (e.g., /admin).
  + **Mitigation**: Implement strict role-based access controls and server-side validation of permissions.

#### Medium Difficulty Detection:

* + Use a testing tool to enumerate endpoints and check for unauthorized access (e.g., Postman).
  + **Mitigation**: Use security headers and enforce access control checks at all endpoints.

#### High Difficulty Detection:

* + Conduct a manual review of business logic in the application to find subtle access control flaws.
  + **Mitigation**: Perform regular code reviews and audits, including testing for business logic vulnerabilities.

## Cryptographic Failures

### Description

Cryptographic failures involve insecure cryptographic practices, leading to data exposure or manipulation.

### Occurrence

Occurs when sensitive data is improperly encrypted or when weak algorithms are used.

### Risk Measure

Risk Level: High. Can result in sensitive data exposure, leading to identity theft or fraud.

### Implementation example

#### Easy Detection:

* + Inspect traffic with tools like Wireshark to find unencrypted sensitive data (e.g., passwords).
  + **Mitigation**: Enforce encryption (e.g., TLS) for data in transit and at rest.

#### Medium Difficulty Detection:

* + Analyze code for hard-coded keys or weak encryption algorithms.
  + **Mitigation**: Use strong encryption standards (e.g., AES) and secure key management practices.

#### High Difficulty Detection:

* + Conduct a security audit to uncover vulnerabilities in custom cryptographic implementations.
  + **Mitigation**: Regularly update cryptographic libraries and use vetted libraries instead of custom solutions.

## Injection

### Description

Injection vulnerabilities occur when untrusted data is sent to an interpreter, leading to execution of unintended commands.

### Occurrence

An application is vulnerable to injection attacks when:

* User input is not validated, filtered, or sanitized by the application.
* Dynamic queries or non-parameterized calls without context-aware escaping are used directly in the interpreter:
  + Query: SELECT \* FROM users WHERE username = '" + user\_input + "';.
  + Injection: SELECT \* FROM users WHERE username = 'anything' OR '1'='1';
* Hostile data is directly used or concatenated in SQL queries or system commands.
  + Exemple command:

<?php

$domain = $\_GET['domain'];

system("ping -c 4 " . $domain);

?>

* + Exemple Injection:

example.com; ls

### Risk Measure

Risk Level: High. Can lead to data loss, data corruption, or unauthorized access to systems.

### Implementation example

#### SQLi :

SQL injection (SQLi) is a security vulnerability that allows attackers to inject malicious sql quotes into fields processed in the database. Here are four exemple types of SQLi:

##### Basic SQL Injection

* **Description**: Malicious user would inject simple code to alter database queries directly
* **Impact**: Bypassing WHERE clause to skip a signup procedure.
* **Example**: A connection (login/password) field where a malicious user would inject code like “ ‘ OR ‘1’ = ‘1 “ modifying the query to be always true.

##### Blind SQL Injection

* **Description**: Used when there is no error message. An attacker would use SQL queries like Time based SQLi (SLEEP) or conditional statements (TRUE/FALSE) to check the response from the application.
* **Impact**: Dumping of the entire database, data leaks, unauthorized access
* **Example :** http://example.com/login.php?username=admin' OR IF(1=1, SLEEP(5), 0) –
  + **admin'**: Ends the string for the username.
  + **OR IF(1=1, SLEEP(5), 0)**: This condition will always be true (1=1). If true, the server waits for 5 seconds due to the SLEEP(5) function. If false, it does nothing (0).
  + **--**: This comments out the rest of the SQL query, effectively ignoring the password check.

##### Union-Based SQL Injection

* **Description**: An attacker would use the UNION operator to combine the original SELECT statement with a new SELECT on another table.
* **Impact**: Extracting data from other tables.
* **Example**: http://example.com/search.php?product=shoes' UNION SELECT username, password FROM users --
  + **shoes'**: The attacker terminates the string to inject their SQL.
  + **UNION SELECT**: This combines the results of the original query with another SELECT query.
  + **username, password**: The attacker specifies the columns they want to retrieve from the users table.
  + **FROM users**: This indicates the source of the data for the second query.
  + **--**: This comments out the rest of the SQL query, ignoring any additional clauses.
  + **SQL Query:** SELECT \* FROM products WHERE name = 'shoes' UNION SELECT username, password FROM users --';

##### Error Based SQL Injection

* **Description**: An attacker would exploit error messages to gather database information by using incorrect syntax or invalid column names.
* **Impact**: Reveal database structure in error messages.
* **Example**:

#### XSS :

Cross-Site Scripting (XSS) is a security vulnerability that allows attackers to inject malicious scripts into web pages viewed by other users. There are three main types of XSS:

##### Reflected XSS (Non-Persistent XSS)

* **Description**: The malicious script is not stored on the server but is reflected off a web server via a URL or HTTP request.
* **Impact**: The attack occurs when a user clicks a specially crafted link that includes the malicious script, which is then executed in their browser.
* **Example**: An attacker sends a victim a link that includes a script in a query parameter. When the victim clicks the link, the script runs.

##### Stored XSS (Persistent XSS)

* **Description**: The malicious script is permanently stored on the target server (e.g., in a database, message forum, or comment field).
* **Impact**: When a user accesses the affected page, the script runs in their browser, potentially stealing cookies, session tokens, or other sensitive information.
* **Example**: An attacker posts a malicious comment on a blog. When other users view the comment, the script executes.

##### DOM-based XSS

* **Description**: The vulnerability exists in the client-side code (JavaScript) rather than on the server. The page's JavaScript modifies the DOM (Document Object Model : programming interface for web documentslike an HTML or XML file), allowing programming languages to manipulate the content, structure, and style of web pages dynamicallyand executes the injected script.
* **Impact**: This type can occur when user input is used to manipulate the page without proper validation or sanitization.
* **Example**: A web page uses document.location to read a URL parameter and directly inserts it into the page, allowing an attacker to execute a script.

#### Example of implementation of reflected XSS:

In the website, go to the “contact” form, where the user can fill a form with his name, email and a message:

Secured script

Une image contenant texte, capture d’écran, logiciel, Logiciel multimédia

Description générée automatiquement

Test

A screenshot of a computer

Description automatically generated

Result

A screenshot of a computer

Description automatically generated

Vulnerable script

Une image contenant texte, capture d’écran, logiciel, Logiciel multimédia

Description générée automatiquement

Test

Une image contenant texte, capture d’écran, Police, nombre

Description générée automatiquement

Result

Une image contenant texte, capture d’écran, Police

Description générée automatiquement

Une image contenant texte, capture d’écran, Police

Description générée automatiquement

### Mitigation Strategies

To prevent XSS attacks:

* **Input Validation and sanitization**: Validate and sanitize user inputs.

**Purpose**:

* + Ensure that user inputs conform to expected formats before processing them.
  + Remove or neutralize potentially harmful content from user inputs.

**Implementation**:

* + Use whitelisting to define acceptable input formats (e.g., only allow certain characters, lengths, or types).
  + Reject any input that does not meet these criteria.
  + Validate input on both the client and server sides.
  + Use libraries specifically designed for sanitization, such as DOMPurify for JavaScript or htmlspecialchars, to clean user inputs before rendering them.
  + Avoid using functions that execute code directly from user input, like eval (Evaluate a string as PHP code) or innerHTML, without proper sanitization.
* **Output Encoding**: Encode data before rendering it in the browser.

**Purpose**:

* + Encode data before rendering it in the browser, so any injected scripts are treated as data rather than executable code.

**Implementation**:

* + Use context-specific encoding:
* **HTML Encoding**: Convert characters like <, >, and & to their HTML entities (&lt;, &gt;, &amp;).
* **Attribute Encoding**: Encode data when inserting it into HTML attributes (e.g., using quotes).
* **JavaScript Encoding**: Encode data when it’s included in JavaScript contexts (e.g., escape quotes).
  + Libraries like OWASP’s Java Encoder or other language-specific libraries can help automate this process.
* **Content Security Policy (CSP) and X-XSS-Protection:** Implement a CSP to restrict sources of executable scripts in .htaccess if Apache server, otherwise in all php files. X-XSS-Protection header instructs the browser to activate its built-in XSS protection features.

**Purpose**:

* + CSP : Define which sources of content are allowed to be loaded by the browser, reducing the risk of XSS attacks.
  + X-XSS-Protection can help block some reflected XSS attacks by detecting potential vulnerabilities.

**Implementation**:

* + Set the Content-Security-Policy HTTP header to specify allowed sources for scripts, styles, images, and other resources. For example:

Content-Security-Policy: default-src 'self'; script-src 'self' <https://trusted.cdn.com> (to be replaced by trusted sites like Cloudflare, Amazon CloudFront, Google CDN, jsDelivr,CDNJS)

* + Regularly review and update your CSP to ensure it reflects your application's needs.
  + The X-XSS-Protection header can be added in your web server configuration or in your application code, depending on your setup. Here’s how to add it in Apache environment: In your .htaccess file or in the server configuration file, you can add:

Header set X-XSS-Protection "1; mode=block"

* **HttpOnly and Secure Cookies**: Use these flags to protect cookies from being accessed via JavaScript.

**Purpose**:

* + Protect cookies from being accessed via JavaScript, especially session cookies.

**Implementation**:

* + Use the HttpOnly flag on cookies to prevent JavaScript access. This means cookies cannot be read through document.cookie.
  + Use the Secure flag to ensure cookies are only sent over HTTPS connections, protecting them from interception in transit.
  + Example of setting a cookie with these flags in HTTP response headers:

Set-Cookie: sessionId=abc123; HttpOnly; Secure;

#### High Difficulty Detection:

* + Analyze source code for vulnerable query construction, especially in complex applications.
  + **Mitigation**: Conduct regular code reviews and security testing, including fuzzing.

## Insecure Design

### Description

Insecure design refers to flaws in application design that fail to consider security risks.

### Occurrence

Often seen in applications lacking a security-focused design phase.

### Risk Measure

Risk Level: Medium to High. Can lead to multiple security vulnerabilities if not addressed during the design phase.

### Implementation example

#### Easy Detection:

* + Review application features for unnecessary data exposure (e.g., error messages revealing stack traces).
  + **Mitigation**: Adopt secure design principles and perform threat modeling.

#### Medium Difficulty Detection:

* + Analyze application workflows for security gaps during user interactions.
  + **Mitigation**: Conduct security reviews during the design phase, involving security experts.

#### High Difficulty Detection:

* + Perform a comprehensive architecture review to identify inherent security flaws.
  + **Mitigation**: Utilize frameworks and best practices for secure design.

## Security Misconfiguration

### Description

Security misconfiguration occurs when default settings are not changed or when security controls are misconfigured.

### Occurrence

Common in cloud services, web servers, and application settings.

### Risk Measure

Risk Level: Medium. May lead to unauthorized access and data exposure.

### Implementation example

#### Easy Detection:

* + Use security scanning tools (e.g., Nmap) to check for open ports or default credentials.
  + **Mitigation**: Regularly review configurations and change default settings.

#### Medium Difficulty Detection:

* + Conduct manual reviews of application settings and server configurations.
  + **Mitigation**: Implement automated configuration management tools.

#### High Difficulty Detection:

* + Analyze cloud infrastructure configurations for compliance with security policies.
  + **Mitigation**: Utilize Infrastructure as Code (IaC) practices to enforce secure configurations.

## Vulnerable and Outdated Components

### Description

Using outdated libraries or components that have known vulnerabilities can expose applications to attacks.

### Occurrence

Common in projects that rely on third-party libraries or frameworks.

### Risk Measure

Risk Level: Medium to High. Can lead to exploitation if vulnerabilities in components are publicly known.

### Implementation example

#### Easy Detection:

* + Scan the application with tools like Snyk to find outdated dependencies.
  + **Mitigation**: Regularly update dependencies and monitor for vulnerabilities.

#### Medium Difficulty Detection:

* + Review the dependency tree for known vulnerabilities using tools like npm audit.
  + **Mitigation**: Establish a regular update schedule for dependencies.

#### High Difficulty Detection:

* + Conduct a manual code review to identify indirect dependencies and their vulnerabilities.
  + **Mitigation**: Adopt a policy for evaluating and vetting third-party components.

## Identification and Authentication Failures

### Description

Failures in user authentication and session management can allow attackers to gain unauthorized access.

### Occurrence

Often found in applications with weak password policies or improper session handling.

### Risk Measure

Risk Level: High. Can lead to account takeovers and unauthorized actions.

### Implementation example

#### Easy Detection:

* + Test for weak passwords or lack of account lockout mechanisms.
  + **Mitigation**: Implement strong password policies and multi-factor authentication (MFA).

#### Medium Difficulty Detection:

* + Analyze session management logic for vulnerabilities (e.g., session fixation).
  + **Mitigation**: Use secure session management practices, including token expiration.

#### High Difficulty Detection:

* + Review authentication code for insecure implementations or patterns.
  + **Mitigation**: Conduct regular security assessments and code reviews focused on authentication.

## Software and Data Integrity Failures

### Description

Failures related to the integrity of software and data can allow unauthorized modifications.

### Occurrence

Common in applications that lack proper integrity checks for their software and data.

### Risk Measure

Risk Level: Medium. Can lead to tampering with application logic or data.

### Implementation example

#### Easy Detection:

* + Check if application updates are performed without validation (e.g., file downloads without checks).
  + **Mitigation**: Implement cryptographic checksums to verify software integrity.

#### Medium Difficulty Detection:

* + Analyze the update mechanism for security flaws (e.g., lack of secure channels).
  + **Mitigation**: Use secure transmission methods and validate all data inputs.

#### High Difficulty Detection:

* + Conduct a thorough review of the software update processes and integrity verification methods.
  + **Mitigation**: Implement comprehensive integrity checks and monitoring systems.

## Security Logging and Monitoring Failures

### Description

Inadequate logging and monitoring can prevent timely detection of security breaches.

### Occurrence

Common in applications that do not maintain detailed logs of user activity or security events.

### Risk Measure

Risk Level: Medium. Delays in breach detection can lead to more extensive damage.

### Implementation example

#### Easy Detection:

* + Review application logs for missing events or anomalies.
  + **Mitigation**: Implement comprehensive logging for all security-related events.

#### Medium Difficulty Detection:

* + Analyze log configurations for security and compliance.
  + **Mitigation**: Regularly review and test logging configurations.

#### High Difficulty Detection:

* + Perform a security audit to evaluate the effectiveness of logging and monitoring systems.
  + **Mitigation**: Establish incident response plans and regular monitoring reviews.

## Server-Side Request Forgery (SSRF)

### Description

SSRF vulnerabilities allow attackers to send unauthorized requests from a server to internal resources.

### Occurrence

Often found in web applications that fetch resources without proper validation of input URLs.

### Risk Measure

Risk Level: High. Can lead to access of sensitive data or internal services.

### Implementation example

#### Easy Detection:

* + Attempt to submit a malicious URL that points to internal resources (e.g., http://localhost:8080).
  + **Mitigation**: Validate and sanitize all input URLs before processing.

#### Medium Difficulty Detection:

* + Use testing tools to send crafted requests to the application.
  + **Mitigation**: Implement network segmentation to limit server access.

#### High Difficulty Detection:

* + Conduct a thorough review of the codebase to find vulnerable request handling.
  + **Mitigation**: Apply strict access controls and regular security

# Discussion

* Analysis of the results in the context of the objectives.
* Comparison with findings from the literature review.
* Implications of the findings for theory, practice, or policy.

# Conclusion

* Summary of key findings.
* Reiteration of the significance of the study.
* Suggestions for future research or recommendations based on findings.

# References

1. **OWASP Foundation.** (2021). *OWASP Top Ten 2021: The Ten Most Critical Web Application Security Risks*. Available at: https://owasp.org/www-project-top-ten/
2. **OWASP Foundation.** (2021). *OWASP Cheat Sheet Series*. Available at: https://cheatsheetseries.owasp.org/

**Cybersecurity Literature**

1. **Shostack, A.** (2014). *Threat Modeling: Designing for Security*. Wiley.
   * This book discusses various vulnerabilities and how to design systems with security in mind.
2. **Hawkins, J.** (2021). *Web Application Security: A Beginner's Guide*. McGraw-Hill Education.
   * This resource provides insights into web application security, vulnerabilities, and mitigation strategies.

**Security Blogs and Whitepapers**

1. **Krebs, B.** (2021). *Krebs on Security*. Available at: <https://krebsonsecurity.com/>
   * A blog that provides insights and analyses on security incidents and vulnerabilities.
2. **OWASP Foundation.** (2021). *OWASP Security Blog*. Available at: https://owasp.org/www/blog/
   * Regular updates on vulnerabilities and security best practices from the OWASP community.

**Security Testing Tools**

1. **PortSwigger.** (2021). *Burp Suite Documentation*. Available at: https://portswigger.net/burp/documentation
   * Documentation for using Burp Suite, a popular tool for web application security testing.
2. **Snyk.** (2021). *Snyk Documentation*. Available at: https://docs.snyk.io/
   * Guidance on using Snyk for identifying vulnerabilities in open-source dependencies.

**Cybersecurity Training Resources**

1. **Coursera.** (2021). *Web Application Security Courses*. Available at: <https://www.coursera.org/courses?query=web%20application%20security>
   * A variety of courses focusing on web application security principles and practices.
2. **Udemy.** (2021). *Web Application Security: The Complete Guide*. Available at: https://www.udemy.com/course/web-application-security-the-complete-guide/
   * An online course that covers a comprehensive range of web security topics.
3. **Cybrary.** (2021). *Web Application Security Courses*. Available at: https://www.cybrary.it/course/web-application-security/
   * Training resources focused on web application security and the OWASP Top Ten.

**OWASP (Open Web Application Security Project)**:

* OWASP provides comprehensive resources on web security risks and best practices, including guidelines for preventing XSS attacks.
* Website: [owasp.org](https://owasp.org)

**MDN Web Docs (Mozilla Developer Network)**:

* MDN offers detailed documentation on web technologies, including security headers like CSP.
* Website: [developer.mozilla.org](https://developer.mozilla.org)

**W3C (World Wide Web Consortium)**:

* The W3C provides specifications and best practices for web technologies, including the CSP specification.
* Website: [w3.org](https://www.w3.org)

**NIST (National Institute of Standards and Technology)**:

* NIST provides guidelines and standards for security practices, which can include web application security.
* Website: [nist.gov](https://www.nist.gov)

**Books on Web Security**:

* Titles like "Web Application Security: A Beginner's Guide" and "The Web Application Hacker's Handbook" cover many security concepts in detail.

# Appendices

* + Additional materials that support the report (e.g., raw data, questionnaires, detailed calculations).

# Acknowledgments

* + Recognition of individuals or organizations that contributed to the project.

# Executive Summary

* + A condensed version of the report, summarizing key points for decision-makers (if the report is for an audience that requires quick insights).