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# Disaster preparedness paradox: Evidence of lower public readiness for extreme rainfall compared to super tropical cyclones in Hong Kong

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## Abstract

As anthropogenic climate change intensifies hydro-meteorological hazards, understanding public preparedness is critical for resilience. This study investigates a pivotal yet understudied question: whether the public prepares differently for large-scale, forecasted super tropical cyclones versus sudden-onset, hyper-localized extreme rainfall. Through a survey of 502 Hong Kong residents following two major hazard events in 2023, the study uncovers a significant "preparedness paradox." Despite higher perceived personal risk from extreme rainfall, public readiness was substantially lower than for typhoons, revealing a critical gap in risk management. Regression analyses demonstrate that preparedness drivers are hazard-specific: being female predicted greater preparedness for extreme rainfalls, while being married was only significant for super typhoon readiness. Non-local-born status and lower income consistently enhanced preparedness for both hazards. The most robust predictor for both hazards was information-seeking through traditional channels. These findings necessitate a strategic shift from one-size-fits-all approaches to hazard-specific, population-tailored initiatives to bridge this preparedness gap and enhance urban resilience in an era of escalating climate extremes.

**Keywords:** disaster preparedness, risk perception, hazard knowledge, risk information seeking, urban resilience

## Introduction

Anthropogenic climate change is intensifying hydro-meteorological hazards, posing a paramount challenge to global resilience [1,2]. Among these, tropical cyclones and extreme rainfall events are consistently the deadliest and costliest disasters in both developed and developing countries [1,3]. They trigger catastrophic flooding, landslides, and widespread infrastructure failure, testing the limits of societal adaptation. A stark example is Hurricane Harvey, whose extreme rainfall caused over 70 fatalities and economic losses exceeding USD 150 billion, ranking it one of the costliest natural disasters in US history [4].

The dynamics of super tropical cyclones and extreme rainfall are intertwined, as both can exacer-

**Availability of data and material**
Upon reasonable request, the datasets of this study can be available from the corresponding author.

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The article is prepared by a single author.

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The study was reviewed and approved by the Survey and Behavioural Research Ethics Committee at the Chinese University of Hong Kong (Ref. SBRE-22-0240).

bate natural disasters such as flooding and landslides [5]. However, the disaster risk management of super tropical cyclones and extreme rainfall is different based on existing scientific and management frameworks. A super tropical cyclone is a large-scale, multi-hazard event, characterized by destructive winds, storm surge, and prolonged rainfall [1]. Tropical cyclones are categorized regionally as hurricanes (North Atlantic and Northeast Pacific), typhoons (Northwest Pacific), or cyclones (South Pacific and Indian Ocean) based on their basin of origin. However, their predictability days in advance, leveraging the existing improved global cyclone monitoring and forecasting system [6,7] enables coordinated, society-wide mobilization in different areas [8,9]. For example, during Cyclone Sidr in Bangladesh in 2007, effective early warning systems allowed for protective measures and timely evacuations, thereby saving lives [10]. These society-wide mobilizations require collaboration among various stakeholders, including government bodies, non-governmental organizations, and the public, to develop effective strategies encompassing preparedness, evacuation, and recovery from cyclone-related disasters [11].

In stark contrast, extreme rainfall—whether isolated or embedded within a larger storm—is often a sudden-onset, hyper-localized phenomenon defined by intense precipitation rates [12,13]. Forecasting extreme rainfall events is inherently complex and influenced by meteorological conditions that may not manifest until shortly before an event occurs. Dynamic and thermodynamic changes in the climate affect the predictability of precipitation extremes, making it difficult to accurately forecast the timing and location of extreme rainfall events [14]. While improvements in forecasting technologies have been made, the inherent variability and spatial complexity of extreme rainfall mean that many events remain poorly predicted, particularly those exceeding specific intensity thresholds. The inability to issue timely warnings results in unprepared communities, exacerbating the potential for catastrophic impacts [15]. The intensification of hourly rainfall extremes due to changing climate conditions has outpaced advancements in forecasting capabilities [16], resulting in a critical mismatch between actual risks and community preparedness. This disparity leads to a mismatch between reality and preparedness. Areas that experience cumulative rainfall exceeding historical averages are particularly susceptible to flooding, which can overwhelm existing infrastructure, such as the extreme rainfall event in Henan Province, China [17].

Although the individual risks of both super tropical cyclones and extreme rainfall are well-documented [e.g., 1, 4]A critical gap remains in our understanding of how these fundamental differences in hazard manifestation shape the experiences and responses of different population groups in society. Assuming preparedness for one equates to preparedness for the other is a potentially fatal miscalculation. To address this, a comparative analysis is indispensable for advancing the science of disaster risk reduction. Consequently, this study moves beyond academic refinement to provide an urgent, empirical investigation into public preparedness for super tropical cyclones and extreme rainfall events, offering critical insights for crafting targeted policies that enhance community resilience and save lives.

This study uses the Hong Kong Special Administrative Region (i.e., Hong Kong) as a case study to compare public preparedness for super tropical cyclones and extreme rainfall events. As one of the world's most densely populated cities, Hong Kong faces unique challenges in disaster risk management and resilience [18]. The city's advanced risk-mitigation infrastructure [19], socioeconomic diversity [9], and comprehensive data resources [20,21] make it an optimal setting for examining public disaster preparedness. Hong Kong's geographical position on the southeast coast of China renders it vulnerable to severe weather events, particularly typhoons and rainstorms. On average, the region experiences approximately five typhoons annually, which can lead to significant economic losses associated with wind, storm surges, and heavy rainfall, accounting for a substantial portion of weather-related damage [20,22,23]. The typhoon season, combined with Hong Kong's subtropical monsoon climate, characterized by an average annual rainfall of around 2,431 mm, exacerbates the risks of landslides, flooding, and infrastructural damage [24,25]. For instance, severe events like Super Typhoon Hato and Super Typhoon Mangkhut not only necessitated the issuance of the highest-level tropical cyclone warning signals but also caused significant disruptions in urban life, including property damage from falling trees and shattered building glass [26]. Furthermore, ongoing climate change has been linked to predictions of more intense and frequent rainstorms, complicating disaster preparedness and response strategies in this densely populated urban environment [27,28]. Therefore, by combining frequent hazard exposure, a diverse and dense population, advanced infrastructure, and available data, Hong Kong provides a unique and informative setting for comparative research on public preparedness for both super typhoons and extreme rainfall events.

By systematically investigating the nuances in the public's risk perception, hazard knowledge, information seeking and preparedness actions across two hazard contexts, this research aims to uncover critical, hazard-specific barriers and facilitators to adaptive behavior. Ultimately, this study provides a foundational framework for developing integrated, multi-hazard preparedness plans that are robust, adaptive, and capable of mitigating compound risks in an era of escalating climate volatility, moving beyond single-hazard paradigms to enhance societal resilience comprehensively.

## Methods

### Hazard events

#### *Super Typhoon Saola*

Super Typhoon Saola, which formed in late August 2023, rapidly intensified into a powerful Category 5-equivalent storm by the end of the month. It was the ninth numbered typhoon event (no. 2309) in the 2023 typhoon season over the Northwestern Pacific Basin. It posed a grave threat to the Philippines, Taiwan, and Southern China, reaching its peak intensity as it approached the coast. The storm's most critical impact came on September 1–2, when it made its closest approach to Hong Kong, necessitating the issuance of the city's highest Hurricane Signal No. 10. Saola finally made its first official landfall in Guangdong province, China, on September 2, bringing catastrophic winds and a significant storm surge, cementing its place as one of the most intense typhoons of the 2023 Pacific season [29].

In Hong Kong, the official report documented that more than 86 people were injured, and authorities received over 3,000 reports of fallen trees, 21 reports of flooding, and 7 reports of landslides during its passage [29]. The typhoon also resulted in widespread disruption, with approximately 40 incidents of damaged scaffolding, signboards, and windows, and caused temporary power outages in some areas [29]. The economic impact was significant, with one assessment estimating the direct economic losses from Saola in Hong Kong to be around HKD 0.48 billion, a figure that rose to a combined HKD 1.9 billion when considered with a subsequent record-breaking rainstorm [30]. The storm's intensity was notable, with maximum sustained winds near its center recorded at 210 km/h, setting a new record for the city [29]. The associated storm surge led to serious flooding in low-lying coastal areas, including Sha Tin, Tai Po, and Tai O. The disruption to city functions was substantial, culminating in the cancellation of 460 flights at the Hong Kong International Airport [29].

## 2023 Extreme Rainfall Event

The 2023 Extreme Rainfall Event, triggered by the remnant low-pressure trough of Typhoon Haikui (no. 2311), was a catastrophic event for Hong Kong, setting multiple historical rainfall records and causing severe city-wide disruption [31]. Typhoon Haikui landed in Taiwan on 3 September and Fujian again on 5 September, over 800 km away from Hong Kong, prompting only the lowest tropical cyclone warning signal in Hong Kong. However, from the night of 7 September to the morning of 8 September 2023, the Hong Kong Observatory (HKO) recorded an unprecedented hourly rainfall of 158.1 millimeters, the highest since records began in 1884 [30,31]. The Black Rainstorm Warning Signal, meaning extremely heavy rain, exceeding 70 millimeters per hour across the city, was in force for 16 hours and 35 minutes, the longest duration since the warning system's introduction in 1992 [31]. The event overwhelmed urban infrastructure, resulting in widespread consequences: more than 140 injuries were reported, and authorities received over 60 reports of flooding and 200 reports of landslides [31]. The torrential rain caused dramatic scenes of flooding in MTR stations, such as Wong Tai Sin Station, and shopping malls, leading to the partial suspension of the Kwun Tong Line and leaving vehicles submerged on major roads like Lung Cheung Road [30,31].

## Research design

This study employed a comparative cross-sectional design to investigate differences in the general public's disaster preparedness for two distinct major hazards in Hong Kong: Super Typhoon Saola and the 2023 Extreme Rainfall Event. Data was collected via an online questionnaire survey following both events, enabling a direct comparison of risk perception, hazard knowledge, risk information seeking, and preparedness behaviors between the two hazards. This methodological approach allows for the identification of hazard-specific variations in the public's readiness, providing critical insights for targeted disaster risk management and policy development.

## Measurements

### *Disaster preparedness*

Disaster preparedness for both Super Typhoon Saola and the 2023 Extreme Rainfall Event was measured by the adoption of 10 different preparedness measures [23,32]. For each measure, respondents selected "yes", "no", or "not applicable" (NA). A composite preparedness score was calculated for each individual as the proportion of applicable measures for which they responded "yes", resulting in a continuous variable ranging from 0 to 1, where a higher score indicates a greater level of disaster preparedness.

### *Risk perception*

Risk perception for Super Typhoon Saola and the 2023 Extreme Rainfall Event was measured using a multi-item index. Respondents rated, on 5-point Likert scales, the perceived likelihood of a similar future event (1=very low to 5=very high possibility) and the anticipated severity of impacts both on a personal/familial level and for Hong Kong in general (1=no impacts to 5=critical impacts). An aggregate risk perception score (range: 0–5) for each hazard was computed by averaging these three dimensions (perceived future occurrence possibility, perceived impacts on individuals and families, and perceived impacts on Hong Kong), where a higher score indicates a greater perceived risk [9,23].

### *Hazard knowledge*

Hazard knowledge for each hazard was measured using two objective, multiple-choice questions [9,28]. For typhoon knowledge, respondents identified the highest Tropical Cyclone Warning Signal (No. 10) and the wind speed threshold for a No. 8 Signal (63–117 km/h). For heavy rainstorm knowledge, they identified the highest Rainstorm Warning Signal (Black) and the rainfall threshold for its issuance (70 mm). A composite knowledge score (range: 0–2) was calculated for each hazard by summing the number of correct answers, with a higher score indicating a greater level of factual hazard knowledge.

### *Risk information seeking*

Risk information seeking was operationalized as the breadth of information channel utilization for each hazard [23,33]. This construct was measured using two distinct variables: the utilization of traditional channels (range: 0–5), encompassing television, radio, newspapers, magazines, the HKO hotline, and oral information from friends, family, neighbors, or colleagues; and the utilization of new channels (range: 0–3), including smartphones, tablets, computers, social media, and the Hong Kong Observatory's website or mobile application. For each respondent and hazard, a composite score was derived by summing the total number of channels used across both categories. Higher scores indicate a greater breadth of risk information exposure and, consequently, a higher level of risk communication engagement [23].

### *Sociodemographic*

A range of sociodemographic variables was included in the analysis. Individual-level factors included gender, age, education level, marital status, and migration status. Household-level characteristics captured economic and housing conditions, including monthly family income, housing type, accommodation tenure, community living duration, household size, and residence area (including proximity to a river). Finally, family healthcare needs were assessed by the presence of children, elderly members, individuals with chronic diseases, and individuals with disabilities in the household. Except for age, all variables were measured categorically for analysis.

## Data collection

First-hand data were collected through an online questionnaire survey (Google Forms) in Hong Kong from 10 September to 31 October 2023. This data collection period commenced within two months of the occurrence of the two selected hazard events. Non-probability sampling was utilized, targeting Hong Kong citizens aged 18 or above holding a valid Hong Kong Identity Card, whether permanent or non-permanent residents. A pilot study was conducted beforehand to ensure that the questionnaire was valid, reliable, and effective. The survey was distributed via the affiliated university's internal platforms and locally popular social media channels, including WeChat groups, WhatsApp groups, Facebook, and LinkedIn. After removing respondents not meeting the selection criteria, the final sample size consisted of 502 participants.

The study received ethical approval from the Secretary of Survey and Behavioral Research Ethics Committee at The Chinese University of Hong Kong, in accordance with the Declaration of Helsinki (Ref. SBRE-22-0240, approved in December 2022).

## Data analysis

Initial descriptive statistics characterized the sample's sociodemographic profile, including individual factors, family economic and housing conditions, and healthcare needs. To compare disaster preparedness and individual disaster risk management between Super Typhoon Saola and the 2023 Extreme Rainfall Event, paired-sample tests were employed; specifically, McNemar's test for categorical outcomes and the Wilcoxon Signed-Rank Test for continuous, non-normally distributed variables, with a significance level of $p<0.05$. Furthermore, multivariate linear regression models were constructed to identify the significant influencing factors—including risk perception, hazard knowledge, risk information seeking, and sociodemographic variables—on the level of preparedness for each hazard. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Version 28.0.1.0).

## Results

### Descriptive analysis of participants

The study sample (N=502) was characterized by a majority of female participants (64.7%) and a relatively young demographic profile, with 51.0% aged 21–40 and 29.5% aged 18–20 (Table 1). The cohort was highly educated, with 86.3% having attained a postsecondary qualification, and predominantly unmarried (80.9%). In terms of socioeconomic and housing conditions, family income was distributed across low (30.3%), middle (37.5%), and high (32.3%) groups. A majority lived in private housing (59.2%), though rental tenancy was common (62.7%). Most participants were long-term residents of their community, with over half (52.4%) living in the same area for more than ten years, primarily in the New Territories (56.2%). Regarding family healthcare needs, a minority of households included children (28.7%) or elderly people (16.5%), while 19.9% reported a member with a chronic disease and 6.6% had a member with a disability.

### Descriptive analysis of disaster preparedness

The analysis of preparedness measures for Super Typhoon Saola and the 2023 Extreme Rainfall Event revealed a statistically significant difference in public readiness between the two distinct hazards. Descriptive statistics indicated a consistently higher prevalence of preparedness actions for Super Typhoon Saola than the 2023 Extreme Rainfall Event across most measures. This pattern was confirmed by McNemar's tests, which identified significant differences ($p<0.001$) for fundamental actions such as buying more food, reducing going out, checking doors/windows, securing outdoor objects, and checking official updates. While measures like clearing drainage outlets, living in risk areas, and monitoring specific hazards showed no significant difference, relocating vehicles and monitoring employer/school notifications were significantly different at $p<0.05$. Critically, the overall disaster preparedness score, analyzed using the Wilcoxon Signed-Rank test, was significantly higher for Typhoon Saola (Mean=0.68, SD=0.18) compared to the 2023 Extreme Rainfall Event (Mean=0.65, SD=0.22; $p<0.05$).

Moreover, the analysis of preparedness by population subgroups (Table 2) revealed significant sociodemographic and socioeconomic disparities in readiness for both Super Typhoon Saola and the 2023 Extreme Rainfall Event. A consistent pattern emerged, indicating that vulnerability and resources shaped preparedness levels. For both hazards, married individuals, non-local-born residents, those with shorter community tenure (<10 years), and families with children demonstrated significantly higher preparedness scores ($p<0.05$). A pronounced socioeconomic gradient was evident, as individuals in the lowest (<HKD 20,000) and middle (HKD 20,000–39,999) income brackets were significantly better prepared than their high-income (≥HKD 40,000) counterparts ($p<0.05$). Notably, the disparity by gender was significant only for the rainfall event, with females reporting higher preparedness than males ($p<0.01$). Conversely, factors such as age, education (for the rainfall event), housing type, accommodation tenure, and the presence of elders or members


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**Table 1. Descriptive statistics of participants**

| Variables | | | Total sample | | Preparedness for super typhoon Saola | | Preparedness for 2023 extreme rainfall event | |
|---|---|---|---|---|---|---|---|---|
| | | | N | % | Mean (SD) | ANOVA test | Mean (SD) | ANOVA test |
| Individual sociodemographic factors | Gender | Male | 177 | 35.3 | 0.66 (0.20) | F(1)=3.584, p=0.059 | 0.61 (0.25) | F(1)=10.037, p<0.01 |
| | | Female | 325 | 64.7 | 0.69 (0.18) | | 0.67 (0.20) | |
| | Age | 18–20 | 148 | 29.5 | 0.68 (0.17) | F(2)=0.805, p=0.447 | 0.66 (0.23) | F(2)=0.598, p=0.550 |
| | | 21–40 | 256 | 51.0 | 0.67 (0.20) | | 0.64 (0.23) | |
| | | Above 40 | 98 | 19.5 | 0.69 (0.17) | | 0.66 (0.19) | |
| | Education | Secondary or below | 69 | 13.7 | 0.71 (0.18) | F(1)=2.912, p=0.089 | 0.65 (0.24) | F(1)=0.022, p=0.883 |
| | | Post-secondary | 433 | 86.3 | 0.67 (0.18) | | 0.65 (2.22) | |
| | Marital status | Unmarried/ others | 406 | 80.9 | 0.67 (0.19) | F(1)=7.807, p<0.01 | 0.64 (0.23) | F(1)=1.547, p=0.214 |
| | | Married | 96 | 19.1 | 0.72 (0.16) | | 0.68 (0.20) | |
| | Migration status | Local-born | 333 | 66.3 | 0.66 (0.18) | F(1)=5.712, p<0.05 | 0.63 (0.22) | F(1)=6.784, p<0.01 |
| | | Non-local born | 169 | 33.7 | 0.70 (0.18) | | 0.69 (0.22) | |
| Family economic and housing conditions | Household monthly income | <HKD 20,000 | 152 | 30.3 | 0.69 (0.19) | F(2)=3.626, p<0.05 | 0.67 (0.23) | F(2)=4.253, p<0.05 |
| | | HKD 20,000–39,999 | 188 | 37.5 | 0.69 (0.17) | | 0.67 (2.22) | |
| | | ≥HKD 40,000 | 162 | 32.3 | 0.64 (0.19) | | 0.61 (0.21) | |
| | Housing type | Public housing | 205 | 40.8 | 0.68 (0.19) | F(1)=0.000, p=0.997 | 0.66 (0.22) | F(1)=0.130, p=0.719 |
| | | Private housing | 297 | 59.2 | 0.68 (0.18) | | 0.65 (0.22) | |
| | Accommodation tenure | Self-occupied | 187 | 37.3 | 0.68 (0.19) | F(1)=0.030, p=0.863 | 0.65 (0.24) | F(1)=0.026, p=0.872 |
| | | Rental | 315 | 62.7 | 0.68 (0.18) | | 0.65 (0.19) | |
| | Community living duration | 0 to 10 years | 239 | 47.6 | 0.70 (0.17) | F(1)=6.523, p<0.05 | 0.68 (0.22) | F(1)=7.359, p<0.01 |
| | | More than 10 years | 263 | 52.4 | 0.66 (0.19) | | 0.62 (0.22) | |
| | Household member(s) | 1 person | 29 | 5.8 | 0.69 (0.14) | F(4)=1.404, p=0.231 | 0.66 (0.22) | F(4)=1.809, p=0.126 |
| | | 2 persons | 89 | 17.8 | 0.66 (0.20) | | 0.65 (0.23) | |
| | | 3 persons | 132 | 26.4 | 0.65 (0.20) | | 0.61 (0.23) | |
| | | 4 persons | 157 | 31.4 | 0.68 (0.17) | | 0.67 (0.21) | |
| | | 5 persons or more | 93 | 18.6 | 0.71 (0.16) | | 0.67 (0.22) | |
| | Residence area | New territories | 53 | 10.6 | 0.70 (0.16) | F(2)=0.312, p=0.732 | 0.67 (0.21) | F(2)=0.350, p=0.705 |
| | | Kowloon | 167 | 33.3 | 0.67 (0.19) | | 0.65 (0.22) | |
| | | Hong Kong Island | 282 | 56.2 | 0.68 (0.18) | | 0.64 (0.22) | |
| | River nearby | No | 384 | 76.5 | 0.66 (0.19) | F(1)=6.481, p<0.05 | 0.64 (0.22) | F(1)=1.97, p=0.161 |
| | | Yes | 118 | 23.5 | 0.71 (0.17) | | 0.67 (0.22) | |
| Family healthcare needs | Child(ren) in family | No | 358 | 71.3 | 0.66 (0.18) | F(1)=6.688, p<0.05 | 0.64 (0.22) | F(1)=2.348, p=0.126 |
| | | Yes | 144 | 28.7 | 0.71 (0.18) | | 0.67 (0.21) | |
| | Elder(s) in family | No | 419 | 83.5 | 0.68 (0.19) | F(1)=0.063, p=0.802 | 0.65 (0.22) | F(1)=0.011, p=0.918 |
| | | Yes | 83 | 16.5 | 0.68 (0.17) | | 0.65 (0.21) | |
| | Member(s) with chronic disease in family | No | 402 | 80.1 | 0.68 (0.18) | F(1)=0.036, p=0.849 | 0.66 (0.22) | F(1)=1.952, p=0.163 |
| | | Yes | 100 | 19.9 | 0.67 (0.18) | | 0.62 (0.23) | |
| | Member(s) with disabilities in family | No | 469 | 93.4 | 0.68 (0.18) | F(1)=0.011, p=0.916 | 0.65 (0.22) | F(1)=0.017, p=0.895 |
| | | Yes | 33 | 6.6 | 0.68 (0.22) | | 0.64 (0.27) | |

with chronic disease or disabilities did not yield significant differences in preparedness.

## Descriptive analysis of risk perception, hazard knowledge and risk information seeking

The Wilcoxon Signed-Rank tests revealed significant differences in individual disaster risk management between Super Typhoon Saola and the 2023 Extreme Rainfall Event. While overall risk perception was marginally higher for the extreme rainfall event ($p<0.01$), the public perceived a significantly greater future occurrence possibility for super typhoons ($p<0.001$). A critical divergence was observed in the appraisal of consequences: the perceived impacts on individuals and families were higher for the rainfall event ($p<0.01$), yet the impacts on Hong Kong as a whole were judged to be significantly more severe for the typhoon ($p<0.001$). This suggests a nuanced risk assessment where personal threat is distinguished from collective societal disruption. Correspondingly, objective hazard knowledge was significantly higher for the typhoon

**Table 2.** **Descriptive statistics of preparedness measures for super typhoon Saola and the 2023 Extreme Rainfall Event**

| Measure taken | Super typhoon Saola | | | 2023 Extreme Rainfall Event | | | McNemar's test[1] / Wilcoxon Signed-Rank test[2] |
|---|---|---|---|---|---|---|---|
| | No N (%) | Yes N (%) | NA N (%) | No N (%) | Yes N (%) | NA N (%) | |
| 1) Buying more food | 131 (26.1) | 359 (71.5) | 12 (2.4) | 241 (48.0) | 247 (49.2) | 14 (2.8) | p<0.001 |
| 2) Reducing going out | 27 (5.4) | 465 (92.6) | 10 (2.0) | 53 (10.6) | 443 (88.2) | 6 (1.2) | p<0.001 |
| 3) Checking doors and windows | 29 (5.8) | 461 (91.8) | 12 (2.4) | 70 (13.9) | 419 (83.5) | 13 (2.6) | p<0.001 |
| 4) Checking up-to-date official weather updates | 7 (1.4) | 486 (96.8) | 9 (1.8) | 22 (4.4) | 475 (94.6) | 5 (1.0) | p<0.001 |
| 5) Securing outdoor objects | 101 (20.1) | 263 (52.4) | 138 (27.5) | 124 (24.7) | 226 (45.0) | 152 (30.3) | p<0.001 |
| 6) Ensuring all drainage outlets are clear | 170 (33.9) | 224 (44.6) | 108 (21.5) | 158 (31.5) | 222 (44.2) | 122 (24.3) | p=0.312 |
| 7) Living in risk areas (e.g., low-lying/sloping areas, seaside places) and being prepared to evacuate | 67 (13.3) | 97 (19.3) | 338 (67.3) | 74 (14.7) | 90 (17.9) | 338 (67.3) | p=0.607 |
| 8) Monitoring storm surge and slopes for hazards, especially for those who live in low-lying/sloping areas | 55 (11.0) | 114 (22.7) | 333 (66.3) | 66 (13.1) | 105 (20.9) | 331 (65.9) | p=0.189 |
| 9) Relocating vehicles from underground parking lots | 63 (12.5) | 94 (18.7) | 345 (68.7) | 81 (16.1) | 79 (15.7) | 342 (68.1) | p<0.05 |
| 10) Being aware of notifications from one's employers/ schools | 17 (3.4) | 461 (91.8) | 24 (4.8) | 29 (5.8) | 444 (88.4) | 29 (5.8) | p<0.05 |
| Disaster preparedness (0–1) | Mean preparedness score=0.68 (SD=0.18) | | | Mean preparedness score=0.65 (SD=0.22) | | | p<0.05 |

McNemar's test was performed for the binary variables of individual measures taken; the Wilcoxon signed-rank test was performed for the continuous measurement of disaster preparedness (0–1).

(p<0.001). Although traditional information channel utilization remained consistent across both hazards (p=0.700), the use of new information channels was significantly more prevalent during the typhoon (p<0.05) (Table 3).

## Regression analysis of disaster preparedness

Multilevel linear regression models revealed distinct and shared influencing factors on disaster preparedness for Super Typhoon Saola and the 2023 Extreme Rainfall Event, explaining 12.0% and 9.8% of the variance in preparedness scores, respectively (both models p<0.001, Table 4). A key finding was the differential role of gender, where being female was a significant positive predictor of preparedness for the extreme rainfall event (β=0.108, p<0.05) but not for the super typhoon. Conversely, being married was a significant factor only for super typhoon preparedness

**Table 3.** **Descriptive statistics of risk perception, hazard knowledge, and risk information seeking for super typhoon Saola and the 2023 Extreme Rainfall Event**

| Factor | Super typhoon Saola | 2023 Extreme Rainfall Event | Wilcoxon Signed-Rank test |
|---|---|---|---|
| Risk perception | 2.82 (0.60) | 2.88(0.64) | p<0.01 |
| Future occurrence possibility (1–5) | 4.06 (0.81) | 3.91 (0.92) | p<0.001 |
| Perceived impacts on individuals and families (1–5) | 1.63 (0.88) | 1.72 (0.96) | p<0.01 |
| Perceived impacts on Hong Kong (1–5) | 2.76 (0.83) | 3.02 (0.94) | p<0.001 |
| Hazard knowledge (0–2) | 1.55 (0.63) | 1.40 (0.52) | p<0.001 |
| Risk information seeking_traditional information channel utilization (0–5) | 1.33 (0.96) | 1.31 (0.99) | p=0.700 |
| Risk information seeking_new information channel utilization (0–3) | 2.00 (0.95) | 1.94 (0.99) | p<0.05 |

**Table 4. Multivariate linear regression analyses of disaster preparedness for two hazard events**

| Factor | Item | Super Typhoon Saola | 2023 Extreme Rainfall Event |
|---|---|---|---|
| Individual sociodemographic factors | | | |
| Gender (Ref. male) | Female | 0.049, p=0.269 [−0.015, 0.053] | 0.108, p<0.05 [0.009, 0.091] |
| Age | Years | −0.069, p=0.327 [−0.003, 0.001] | −0.046, p=0.520 [−0.003, 0.002] |
| Education (Ref. secondary or below) | Post-secondary | −0.017, p=0.730 [−0.061, 0.043] | 0.055, p=0.270 [−0.028, 0.098] |
| Marital Status (Ref. Unmarried) | Married | 0.134, p<0.05 [0.000, 0.124] | 0.078, p=0.255 [−0.032, 0.119] |
| Migration status (Ref. local-born) | Non-local born | 0.118, p<0.05 [0.005, 0.087] | 0.114, p<0.05 [0.004, 0.103] |
| Family economic and housing conditions | | | |
| Household monthly income (Ref. <HKD 20,000) | HKD 20,000–39,999 | −0.015, p=0.776 [−0.045, 0.033] | −0.027, p=0.607 [−0.060, 0.035] |
| | ≥HKD 40,000 | −0.135, p=0.016 [−0.096, −0.010] | −0.135, p=0.016 [−0.116, −0.012] |
| Housing type (Ref. public housing) | Private housing | −0.019, p=0.702 [−0.043, 0.029] | −0.064, p=0.193 [−0.072, 0.015] |
| Accommodation tenure (Ref. rental) | Self-occupied | 0.073, p=0.153 [−0.010, 0.066] | 0.093, p=0.072 [−0.004, 0.089] |
| Community living duration (Ref. 0–10 years) | More than 10 years | −0.105, p<0.05 [−0.076, −0.002] | −0.099, p=0.057 [−0.089, 0.001] |
| Household members | Number of persons | 0.056, p=0.296 [−0.007, 0.022] | −0.002, p=0.968 [−0.018, 0.017] |
| Residence area (Ref. new territories) | Kowloon | 0.053, p=0.258 [−0.015, 0.057] | 0.030, p=0.523 [−0.029, 0.057] |
| | Hong Kong Island | 0.075, p=0.109 [−0.010, 0.100] | 0.081, p=0.085 [−0.008, 0.125] |
| River nearby (Ref. no) | Yes | 0.108, p<0.05 [0.009, 0.085] | 0.054, p=0.233 [−0.018, 0.074] |
| Family healthcare needs | | | |
| Child(ren) in family (Ref. no) | Yes | 0.068, p=0.190 [−0.014, 0.069] | 0.082, p=0.120 [−0.010, 0.091] |
| Elder(s) in family (Ref. no) | Yes | −0.025, p=0.611 [−0.060, 0.035] | −0.008, p=0.867 [−0.062, 0.052] |
| Member(s) with chronic disease (Ref. no) | Yes | −0.004, p=0.936 [−0.050, 0.046] | −0.061, p=0.251 [−0.092, 0.024] |
| Member(s) with disabilities (Ref. no) | Yes | −0.024, p=0.630 [−0.091, 0.055] | 0.006, p=0.900 [−0.083, 0.095] |
| Hazard-specific | | | |
| Risk perception | Score (0–5) | 0.084, p=0.069 [−0.002, 0.053] | 0.019, p=0.685 [−0.025, 0.038] |
| Hazard knowledge | Score (0–2) | −0.002, p=0.966 [−0.027, 0.026] | 0.009, p=0.836 [−0.034, 0.041] |
| Risk information seeking_Traditional information channel utilization | Score (0–5) | 0.168, p<0.001 [0.015, 0.050] | 0.135, p<0.01 [0.010, 0.051] |
| Risk information seeking_New information channel utilization | Score (0–3) | −0.092, p=0.056 [−0.036, 0.000] | −0.065, p=0.172 [−0.036, 0.006] |
| Model performance | Nagelkerke R square | F(22)=2.950 p<0.001 $R^2$=0.120 | F(22)=2.341 p<0.001 $R^2$=0.098 |

Standard coefficient β, p value and 95% confidence intervals (lower bound and upper bound) were reported for each factor.

(β=0.134, p<0.05). Notably, non-local-born status was a robust, significant predictor for both hazards (Typhoon: β=0.118, p<0.05; Rainfall: β=0.114, p<0.05), suggesting migration background consistently enhances readiness. Socioeconomically, a higher household income (≥HKD 40,000) was associated with significantly lower preparedness for both events (β=-0.135, p=0.016).


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Contextual vulnerability also played a role, as residing near a river significantly increased preparedness for the super typhoon (β=0.108, p<0.05), while longer community tenure (>10 years) significantly decreased it (β=-0.105, p<0.05). Most critically, risk information seeking emerged as the strongest shared driver; utilization of traditional information channels was a highly significant positive predictor for both the super typhoon (β=0.168, p<0.001) and the rainfall event (β=0.135, p<0.01). This underscores that beyond sociodemographics, proactive information-seeking through established channels is a fundamental component of disaster preparedness across hazard types (Table 4).

## Discussion

This study provides critical empirical evidence underscoring the distinct nature of public preparedness and risk management behaviors in the face of super tropical cyclones and extreme rainfall by using data collected from Hong Kong. By explicitly comparing these two increasingly frequent hydro-meteorological hazards within a highly exposed, urbanized context, the findings make clear that existing disaster risk management frameworks must evolve from generic, "all-hazards" approaches to targeted, hazard-specific strategies.

### Distinct hazard dynamics and the preparedness gap

The consistent pattern of greater preparedness for Super Typhoon Saola highlights how hazard predictability, scale, and established response frameworks drive mobilization. Tropical cyclones, characterized by multi-day forecasts and society-wide warnings, elicit concrete preparatory actions across food provisioning, home fortification, and information seeking. In contrast, extreme rainfall events — defined by abrupt onset, localized impact, and ambiguous triggers — struggle to translate heightened risk perception into tangible readiness. These findings confirm previous assertions [13,15] that temporal and spatial uncertainty serve as formidable barriers to adaptive behaviors, and underscore the fatal flaw of assuming cross-hazard preparedness equivalency.

The paradox observed—higher personal risk assessment for extreme rainfall but lower practical preparedness—highlights that psychological salience does not automatically translate into protective action, echoing the well-documented intention–behavior gap in disaster settings [34,35]. Cognitive biases such as optimism bias [36] and normalcy bias [37] may lead individuals to underestimate their vulnerability or delay action despite recognizing high risks. Moreover, ambiguity in onset and a lack of clear preparedness cues for extreme rainfall exacerbate decisional inertia, as outlined by Lindell & Perry [38], who show that perceived efficacy and clarity of recommended actions are critical for mobilization. These findings underscore the necessity for disaster strategies that are psychologically informed, actively bridging the gap between risk awareness and preparedness behavior.

Moreover, the collective framing of tropical cyclone risk (large-scale societal disruption) arguably leverages institutional communication and social norms more effectively than the fragmented, individual experience of extreme rainfall events. This pattern was evident in the lower preparedness scores and in specific actions such as checking windows, securing outdoor objects, and reducing mobility found in Hong Kong, which were significantly less likely during the rainfall event. These results reinforce the necessity to recognize typological differences in hazard manifestation, a crucial step to avoid the "one-size-fits-all" fallacy in disaster readiness campaigns.

### Sociodemographic and socioeconomic inequality in preparedness

The findings strongly corroborate the critical role that socioeconomic and demographic factors play in shaping disaster preparedness. The unexpected inverse relationship between household income and preparedness and extreme rainfall recasts the common assumption that greater economic resources confer higher adaptive capacity, which has been observed for both super tropical cyclones and extreme rainfall. Wealthy individuals may have access to insurance and financial resources that give them a false sense of security, potentially leading to complacency in their preparedness for extreme weather events [39]. Instead, those in low and middle income brackets—often facing greater physical vulnerability and fewer options for external support—demonstrated higher readiness, echoing emerging evidence of adaptive strategies among the economically marginalized.

Migratory status also emerged as a consistent facilitator of preparedness, suggesting that non-local-born residents may be more attuned to disaster communication, possibly reflecting experiences or social networks from prior exposure in different regions. The non-local-born residents' adaptation to new environments necessitates a proactive approach to disaster preparedness. They usually recognize the importance of preparedness as a vital component of successful adaptation in a new locale, making them more inclined to invest in personal safety measures [40].

Therefore, the findings reveal a clear manifestation of the disaster preparedness paradox, wherein awareness and resources fail to translate into adequate preparedness [41]. Specifically, local-born and high-income respondents demonstrated significantly lower preparedness levels, suggesting that entrenched complacency and an optimism bias, potentially born of a history of successful past coping, may suppress protective action despite high objective risk and economic capacity.

Moreover, some predictors of preparedness were not universal but hazard-specific, reflecting the distinct temporal and spatial dynamics of each threat. Factors such as marital status, long community living duration, and proximity to a river emerged as significant only for super tropical cyclone preparedness. This pattern underscores the anticipatory nature of tropical cyclone response: individuals with greater social responsibilities (marriage), long-term local knowledge of community-specific flood risks (proximity to a river) are more motivated and equipped to undertake the complex, multi-step preparations required for a large-scale, forecasted event. Individuals with greater social responsibilities, such as married residents, tend to translate their sense of obligation to protect their loved ones and community members into proactive disaster preparedness measures, including establishing emergency plans and maintaining supplies [42]. Familiar with their surroundings are more likely to recognize the significance of flooding risks and invest time and resources to prepare adequately [43]. This awareness of specific local conditions can lead to more effective preparation strategies tailored to community needs. However, individuals with deep-rootedness in the community (longer community living duration) are less likely to adopt preparedness measures against super tropical cyclones. This confirms the previous findings that individuals with extensive local knowledge might underestimate the likelihood of disasters or view them as part of their daily life, leading to complacency [38]. Their familiarity with the environment can result in overconfidence that diminishes the perceived necessity for proactive measures.

Furthermore, gender differences were hazard-specific, with women showing greater preparedness for extreme rainfall but not for tropical cyclones, highlighting that gendered risk appraisal may vary by hazard type and warrants targeted communication interventions. Women may develop a more nuanced understanding of specific risks associated with extreme rainfalls due to personal experiences in their communities, such as flooding or managing children during hazardous weather, leading to a higher motivation for preparedness [44]. Research indicates that past experiences related to flooding can create stronger emotional connections, driving individuals to adopt preparedness measures [45]. This emotional resilience supports proactive pre-


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paredness for extreme rainfalls and flooding. In contrast, super tropical cyclones in Hong Kong elicit broad community mobilization, reinforced by government-led warnings and standardized, societal preparedness routines [23]. In these situations, approaching risk is highly visible, information is disseminated uniformly, and mass preparations are encouraged. Such collective framing leads both men and women to similar behaviors, as gender differences are mitigated by the shared societal response mechanisms. Last but not least, the lack of significant effects for age, education, and health-related vulnerability further highlights the nuanced, context-dependent drivers of disaster preparedness, breaking with common risk management assumptions.

## The primacy of information-seeking and hazard-specific communication

Most strikingly, information-seeking via traditional information channels emerges as the strongest shared determinant of disaster preparedness on both super tropical cyclones and extreme rainfall events, outstripping even socioeconomic predictors. The significant positive association between traditional information channels and disaster preparedness, contrasted with the non-significant role of new channels, corroborates earlier findings from Hong Kong [23]. This consistent pattern, observed across a five-year interval that included a global pandemic and rapid digitalization, underscores the enduring authority and reliability vested in official, established media during super tropical cyclones and extreme rainfall events.

This also supports calls for strengthening trusted communication infrastructures and adapting real-time messaging to hazard characteristics. The persistently higher use of new media during tropical cyclones suggests that digital integration is increasingly relevant but must be matched by reliable, timely alerts for sudden-onset events like extreme rainfall.

## Policy and practice implications

These findings necessitate a strategic shift away from uniform public education and toward hazard-specific, population-tailored initiatives. Key recommendations include: (1) designing anticipation-driven interventions for tropical cyclones, leveraging structured warning periods for mass mobilization; (2) creating ultra-fast, localized awareness and response mechanisms for extreme rainfall, focusing on clear triggers, actionable guidance, and inclusive outreach; (3) targeting high-income and long-term resident populations with customized campaigns, counteracting complacency or false security typically associated with resource abundance; (4) empowering adaptive groups such as non-local-born and lower-income populations as resilience champions, drawing on their demonstrated engagement; (5) intensifying risk information dissemination across both traditional and digital platforms, with increased clarity on the distinct nature and requirements of super tropical cyclones versus rainfall event preparedness.

## Research limitations

Although this study provides valuable evidence on hazard-specific preparedness in Hong Kong, the issue of sampling bias presents a significant limitation that warrants further consideration. The substantial overrepresentation of female (64.7%) and highly educated (post-secondary degree, 86.3%) respondents may have significantly shaped the observed preparedness patterns, as both females and higher education levels are repeatedly shown to correlate with higher disaster risk perception and adaptive behaviors [44,46]. This sampling structure could therefore lead to inflated estimations of public readiness, particularly for hazards where women and highly educated individuals historically engage more readily in preparedness activities [47]. Moreover, all ten preparedness measures are commonly taken for both typhoons and extreme rainfall in Hong Kong, as extreme rainfall events often coincide with strong winds. However, certain actions, such


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as checking windows and securing outdoor objects, may be more typhoon-specific, indicating the need for more hazard-specific measures in future research.

Furthermore, another major limitation of this study is its reliance on self-reported preparedness behaviors, which, despite being collected within two months of the hazard events, remain susceptible to recall bias and social desirability effects that may inflate or deflate actual readiness upon the specific hazards [48]. This may also influence the observed preparedness paradox. Additionally, the cross-sectional design precludes causal inference and limits understanding of temporal relationships between risk perception and preparedness [49]. Future research should prioritize longitudinal and experimental approaches, expand sampling diversity, and integrate psychometric models to unpack the interplay between risk perception, social norms, and adaptive action.

## Conclusion

The disaster preparedness paradox revealed—lower readiness for extreme rainfall despite its growing threat—signals the urgency of innovation in public disaster risk management. In the face of climate change's intensifying extremes, hazard-specific, demographically tuned, and communication-empowered strategies are essential to closing the preparedness gap and forging resilient communities in Hong Kong and beyond. By recognizing and responding to the nuanced divergence between hazard perception and preparedness action, policymakers can transform this foundational vulnerability into a catalyst for innovation. The ultimate task is not merely to close a preparedness gap, but to forge anticipatory governance systems capable of navigating the complex, cascading risks of an era of climatic uncertainty.

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