

**The Development of a Balance Training
Programme to Prevent Slips, Trips and Falls
at Workplace**

 **Occupational Safety & Health Council**

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Abbreviations

1RM	One rep max
3D	Three dimensional
ANCOVA	Analysis of covariance
ARM	Association of restaurant managers
BBS	Berg balance scale
BMI	Body mass index
BoS	Base of support
CI	Confidence interval
CoM	Center of mass
CREC	Clinical Research Ethics Committee
CUHK	The Chinese University of Hong Kong
EEEGU	Eating Establishment Employees General Union
FaME	Falls management exercise
GBCA	Hong Kong General Building Contractors Association
HKCIEGU	Hong Kong Construction Industry Employees General Union
ICH-GCP	International Conference on Harmonisation – Good clinical practice
IRR	Incidence rate ratio
JISHA	Japan Industrial Safety and Health Association
Mini	Mini balance evaluation systems test
BESTest	
MVPA	Moderate to vigorous physical activity
NTEC	New Territories East Cluster
OEP	Otago exercise program
OSHC	Occupational Safety and Health Council
PA	Physical activity
PolyU	The Hong Kong Polytechnic University
PPE	Personal protective equipment
ProFaNE	The Prevention of Falls Network Europe

RaR	Rate ratio
RCT	Randomized controlled trials
ROC	Receiver operating characteristic
RR	Relative risk
STF	Slips, trips and falls
STFL	Slips, trips and falls on the same level
TMS	Tinetti mobility score
UC	Usual care
VT	Virtual trainer

1 Executive Summary

1.1 Background

Occupational slips, trips and falls on same level (STF) is one of the most common incident types in occupational settings both locally and globally. When compared with different populations across the world, incidence rate (between 20 to 29 per 10,000 workers) and percentage (between 26.7 to 33.0% of all non-fatal incidents) of non-fatal STF in Hong Kong are higher than many regions such as Taiwan, Singapore, Canada, the U.S., Australia, etc. (between 5 to 20 per 10,000 workers; or 8.4-34.0% of all non-fatal incidents). Among the different industries, STF incidence rate is especially high in the manufacturing (between 36 to 46 per 10,000 workers), retail/accommodation/food services (between 32 to 40 per 10,000 workers), and construction (between 25 to 31 per 10,000 workers) industries. The risk of STF increases with age. With an aging working population in Hong Kong, the prevalence of occupational STF will most likely increase in the foreseeable future. Not only do older fallers take longer time to recover from their fall-related injuries, the average medical cost for them is also more expensive than treating a younger faller. In the US alone, the direct cost caused by falls on same level was estimated at USD\$10.62 billion in 2017, which was ranked second and accounted for 17.7% of all injury cost.

STF occur for a variety of reasons in the workplace. In general, risk factors can be categorized into (1) environment/extrinsic factors, (2) human/intrinsic factors, (3) work-related factors, and (4) management factors. Extrinsically, workers should pay closer attention to their work environment (e.g. surface and weather conditions), protective equipment, footwear, and factors that will affect their visual acuity or field (e.g. eyewear, lighting condition, visual obstacles, etc.). Intrinsically, though some factors are non-modifiable or not easily modifiable (e.g. age, gender, health condition), some of which can be improved by providing proper physical training (e.g. functional fitness, muscle mass, body mass index), education (e.g. safety awareness), medication and other substances, and work scheduling (e.g. fatigue management). Other work-related factors include work pace, urgency of task, task-related distractions, shift length, and load carrying. Finally,

management factors include work scheduling (e.g. project timelines, shift work, and urgency of task), company size, safety guidelines on hazard control, safety communication, etc.

Traditionally, much of the STF prevention efforts have been directed towards the environment/extrinsic factors, work-related factors, and/or management factors in occupational settings. However, with an aging working population, it is important for employers, as well as employees, to divert some of their STF preventive efforts into addressing the human/intrinsic factors. Based on our review, many different exercise interventions exist with varying degree of effectiveness in improving balance and reducing fall risk among older adults. Specifically, multi-component exercise intervention including balance, strength, and Tai Chi training has been shown to be the most effective in improving physical performances that correlate to various intrinsic fall risk factors. Furthermore, dual-task training (i.e. combining balance/gait training with motor/cognitive interference) is necessary as workers in various industries are often required to multi-task in their daily work routine.

1.2 Fall prevention exercise programme

The Department of Sports Science and Physical Education of the Chinese University of Hong Kong was entrusted by the Occupational Safety and Health Council to conduct this consultancy study. A fall prevention exercise intervention aimed to reduce STF risk was developed based on the literature and scientific theory, and its effectiveness was verified through a cohort study.

We proposed a 12-week exercise intervention programme in which participating workers were asked to exercise twice a day for five days every week. Each training session lasted around 10-15 minutes to minimize disruption to their usual work schedule, as they could perform these trainings before/ after work, or during their breaks.

There were three types of exercises: static balance training, dynamic balance training, and resistance training. To minimize fatigue, the morning session started off with dynamic warmup exercises followed by static balance training (i.e. standing in different stance while performing other upper body tasks), whereas the afternoon session alternated between dynamic balance training (i.e. walking/hopping/single leg deadlift) and resistance exercises (i.e. upper/lower body and core) aimed to improve muscle power. Tai Chi, a proven fall intervention exercise, was used as cooldown exercises after the afternoon session.

The difficulty of each training module would increase progressively every two weeks (e.g. with more challenging stance, motor/cognitive interference, disrupted sensory input, increasing intensity/magnitude, etc.) to minimize adaptation effect. Monthly workshops were held to instruct participants on how to do these exercises properly. Furthermore, exercise videos were posted online for workers to follow. To remind participants to perform these trainings, a mobile app was used to prompt them to do these exercises based on their preferred schedule. Participants were asked to record their completed training sessions using the mobile app for us to verify their compliance.

Pre- and post-training assessments were conducted to quantify each individual's physical performance and fall risk. Specifically, fall risk was estimated using a shortened version of the JISHA (Japan Industrial Safety and Health Association) questionnaire. Physical performance was evaluated using a few simple tests, i.e. (1) Static balance: Single-leg balance test with eyes closed, (2) Dynamic balance: Functional reach test and Y-balance test, (3) Agility: Four-square step test, and (4) Muscle strength: Five-times sit-to-stand test. Since our participants came from the working population instead of the frailer and older group, these tests were chosen over the common fall risk screening tools (e.g. Berg balance scale (BBS), Tinetti mobility score (TMS), and Mini-BESTest) to avoid ceiling effect.

A cluster-randomized controlled trial involving 105 participants with varying gender, age, height and weight was conducted to establish the effectiveness of the intervention. Due to the pandemic and personal reasons, 12 participants withdrew from our study, leaving 41 participants in the experimental group and 52 in the control group. Most of our participants came from two industries with the highest fall incidence rate in Hong Kong: construction and catering. As hypothesized, the experimental group who underwent 12 weeks of progressive, multi-modal balance training with online video demonstration and reminder had significantly improved balance control in multiple domains (i.e. static balance, dynamic balance, agility, and leg muscle strength and power) in comparison to the control group, regardless of their age and gender. Even physically active construction workers have showed significant improvement in their agility, as well as enhanced static and dynamic balance control. Our findings also showed that people working in the catering industry tended to have greater improvement than construction workers except for static balance, as both groups had improved similarly in that regard. This suggested our proposed intervention should provide even greater benefits for sedentary or less physically active individuals, such as those who mainly sit in front of a desk.

1.3 Recommendations

Improving working environment and management can reduce occupational STF; however, it is equally important to enhance employees' gait and balance control to address the intrinsic factors of STF. Our study has shown that our fall prevention exercises were effective in reducing fall risk by significantly improving our participants' static balance, dynamic balance, agility, and leg muscle power. Furthermore, our results revealed that our proposed intervention could potentially provide greater benefits for sedentary or less physically active individuals. We recommend OSHC and the industry to widely promote this exercise intervention to workers in Hong Kong. In addition, more safety trainings should be provided to raise their safety awareness. In combination with having safer work environment and management, a multi-pronged approach can effectively minimize STF accidents in occupational settings.

In order to lower the fall risk and fall incidence of workers in Hong Kong at the societal level, it is imperative to translate our knowledge to the general public, and to raise their awareness of the importance of personal fitness in fall prevention. OSHC should promote our effort through its website, workshops, and the media. To extend the reach to more workers, OSHC should also collaborate with the government, labour unions, contractors/manufacturers associations, and chambers of commerce to stress the importance of worker health and fall prevention in occupational settings. Ideally, like the construction workers, employees from high fall risk sectors should also be given designated time to perform exercises to prevent occupational accidents and injuries.

2 Introduction

Occupational slips, trips and falls on the same level (STF) are a serious public health concern that affects a significant portion of the working force (Chang, Leclercq, Lockhart, & Haslam, 2016). Previous studies have revealed that STF has accounted for the most accidental injuries and death in occupational settings in Hong Kong (Labour Department, 2017) and other countries (Courtney, Sorock, Manning, Collins, & Holbein-Jenny, 2001). STFs have accounted for more than 1300 cases of injuries in Hong Kong between 2005-2015, ranking third behind injuries caused by hand tools and contact heat (Legislative Council Secretariat, 2017). Such accidents have placed enormous financial burdens on the health care system (Liberty Mutual Research Institute of Safety, 2016).

Hsiao's review (2014) STF-related researches summarized that STFs occur as a result of a complex interaction of risk factors which can be organized into three categories: personal, environmental, and task-related factors. The personal factors include individual differences: age, gender, race, body size, work experience, chronic illness, physical strength, substance use, cognitive capacities, constraints of personal protective equipment (PPE), visual acuity, contrast sensitivity, discrepant vision between the eyes, and expiratory flow rate (Hsiao, 2014). The environmental factors concern the information available from visual and physical interactions with environments, including elevation perception, moving visual scenes, depth perception, visual ambiguity, visual detection of obstacles and their properties, restricted support surfaces, support surfaces inclination, lighting, building design, and material properties of support surfaces (e.g. friction, contaminants, evenness, loose fixtures, and firmness) (Hsiao, 2014). Finally, the task-related factors include load handling, physical exertion and fatigue, footwear, complexity of tasks, social interactions, and community resources (Hsiao, 2014).

Fall has been defined as “an event which results in a person coming to rest inadvertently on the ground or other lower level and other than as a consequence of a violent blow, loss of consciousness, sudden onset of paralysis or an epileptic seizure” (Tinetti, Speechley, & Ginter,

1988). The act of balance involves the controlling of the center of mass (CoM) of our body over the base of support (BoS). Sometimes, due to slips (i.e. the BoS being displaced from underneath the CoM of the body) or trips (i.e. the BoS being impeded to move along with the CoM of the body), a fall may occur. Chang, Leclercq, Lockhart, and Haslam's review (2016) on occupational STFs concluded that researchers have identified that the risk of slip-induced fall accidents is associated with friction demand characteristics during walking, which are in turn affected by factors such as working-pace, turning, load carrying as well as footwear dynamics. It was concluded that although risks of STFs are related to friction demand characteristics, overall fall risk is still directly linked to how one maintains dynamic stability when disrupted (Chang et al., 2016).

When the perturbation magnitude is relatively minor, muscle torque generated around the hip and ankle joints can sometimes help to slow down the CoM motion to restore postural stability. However, when the relative displacement of the CoM and BoS is large, compensatory balance-recovery reactions have to be executed to rapidly expand the BoS (i.e. by taking a step (McIlroy & Maki, 1996; Zettel, Holbeche, McIlroy, & Maki, 2005) or grasping a handhold (Cheng, McKay, King, & Maki, 2012; Cheng, Pratt, & Maki, 2013; Marigold, Bethune, & Patla, 2003)) to prevent a fall from happening (Maki & McIlroy, 2006). The control of these compensatory balance-recovery reactions are extremely sophisticated, as the Central Nervous System (CNS) has to process multimodal sensory input to modulate our limb movements while taking into account the environmental constraints and unexpected body motion induced by the postural disturbance (Maki & McIlroy, 2007). Many of these mental processing can be affected by nature aging, as well as mental fatigue. Furthermore, due to aging, inactivity, and physical fatigue, the body may be unable to execute these rapid compensatory balance-recovery reactions effectively to rescue a fall. As a result, it is necessary to improve one's physical conditioning in order to reduce the risk of falls (Horlings, van Engelen, Allum, & Bloem, 2008).

Fall prevention must be investigated through a multidisciplinary approach. To reduce the number of fall incidence, many different human factors, work-related factors, and physical factors

have to be taken into account (Bentley & Haslam, 2001). Previous researchers have identified many intrinsic factors that would predispose an individual to increased fall risks; for example, older age, female gender, overweight or obesity, poor visual acuity and depth perception, use of bifocal or multifocal glasses, weakened muscle strength, impaired proprioception and balance control, and past history of falls (Campbell, Borrie, & Spears, 1989; Lord, Menz, & Tiedemann, 2003; Shumway-Cook, Baldwin, & Polissar, 1997). With an aging population in Hong Kong (Census and Statistics Department, 2015), it is not surprising that the number of workplace STF will continue to rise. Besides the intrinsic factors, work-related factors such as work pace, workloads, task-related distractions, fatigue can make predisposed workers more susceptible to falls (Bentley & Haslam, 2001). In order to prevent falls from happening, it is necessary to reduce extrinsic fall hazards such as cleaning slippery surfaces, fixing uneven flooring, illuminating dark walkways at workplace, etc. Furthermore, proper footwear with high friction coefficient should be worn to reduce the risk of slipping in high risk sectors such as the catering and construction industries.

In an attempt to identify high-risk fallers at work, the Japan Industrial Safety and Health Association (JISHA) developed a STF risk assessment test in 2009 (Japan Industrial Safety and Health Association, 2010). Besides having 25 questions on a self-reported questionnaire, the test also included five physical fitness tests. Previous studies have shown that a score of 10 points or more were defined as high risk fallers (Toba et al., 2005). However; due to the unpredictability nature of falls, the predictive value of the STF risk assessment test was found to be <15% in order to maintain high sensitivity and specificity in a recently published evaluation study (Nakamura et al., 2016). Furthermore, the same study has found that six (i.e. Q1, Q5, Q11, Q12, Q18, Q25) of the 25 questionnaire items alone would yield similar area under the receiver operating characteristic (ROC) curve as the original JISHA occupational slip, trip and fall risk assessment test, suggesting a shortened version of the questionnaire had the same predictive power as the full version. Tsukada and Sakakibara (2016) conducted a similar study with 436 employees at an electrical appliance manufacturer. It was found that the physical measurements were not significantly associated with the occurrence of falls, but the fall score questionnaire was a good indicator of the workers' fall risk (Tsukada & Sakakibara, 2016). Therefore, other physical tests,

e.g. measuring restabilization time and/or magnitude of imbalance when transitioning from a working posture to quiet standing (DiDomenico, McGorry, & Banks, 2016), may be more sensitive in identifying high risk fallers in occupational settings. Nevertheless, besides the strong need to develop a better STF risk assessment tool with higher predictive power, it is also equally important to enhance the balance control of the aging workforce to reduce the number of occupational STF.

Previous studies on using exercise training for fall interventions in occupational settings have shown various degree of success. For example, Kawagoe et al. (2010) found that a warm up exercise routine known as “radio taiso” could significantly improve physical performance related to fall risk factors. Older workers with a mean age of 57.2 were instructed to perform limbering up exercises with particular emphasis on balance, agility and muscle strength five times a week before work for eight months. The study found significant improvements in static balance, agility, flexibility, and muscle strength, as well as decreased fall risk in the participants at the end of the eight-month intervention (Kawagoe et al., 2010). Similarly, Granacher et al. (2011) conducted an 8-week balance and strength training at a worksite for 32 sedentary office workers, followed by 8 weeks of detraining. The study observed significant improvements in center of pressure displacements, gait velocity, peak isometric/isokinetic torque, rate of torque development of the plantar flexors, and jumping height after training, as well as muscle strength deterioration and improved postural control during detraining (Granacher et al., 2011).

Using more advanced technologies, some studies have incorporated a slip-simulator and/or a virtual reality (VR) platform in order to facilitate kinetic learning as part of their approach of training, education and awareness raising (Lockhart, 2010). By familiarizing participants with slip experience through slip-simulators and/or VR platform in a safe and controlled environment, studies have found that participants have reduced slip severity and improved recovery kinematics post-training (Liu, Lockhart, Parijat, McIntosh, & Chiu, 2015; Parijat, Lockhart, & Liu, 2015a) (Parijat, Lockhart, & Liu, 2015b). However, due to the need to use specialized equipment, this type of training is not practical to be implemented in occupational settings. Therefore, careful

consideration should be given when designing an effective fall prevention programmes for the working population.

2.1 *Project overview*

Due to the high prevalence of slip, trip and fall accidents in occupational settings, the Chinese University of Hong Kong (CUHK) has been awarded HK\$980,000 from the Occupational Safety and Health Council (OSHC) to conduct a Consultancy Study on “The Development of a Balance Training Programme to Prevent Falls at Workplace” that was commenced on the 1st of April 2019. The project was led by Dr. CHENG Chik-chi Kenneth from the Department of Biomedical Engineering (2019-09/2022: CUHK and 10/2022-now: The Hong Kong Polytechnic University), while Prof. HUI Sai-chuen Stanley from the Department of Sports Science and Physical Education (CUHK) was as the budget holder and provided expert advises on exercise prescriptions. The research team also comprised of Prof. CHEUNG Wing-hoi Louis from the Department of Orthopaedics & Traumatology (CUHK) and Prof. TSE Lap-ah Shelly from the Jockey Club School of Public Health and Primary Care (CUHK). With this research grant and the funding support from Prof. Hui, we have hired Research Assistants, Miss CHAN Lok-kwan Kim (04/2019-08/2021) and Mr. WONG Chung-yan Billy (09/2021-07/2022) to prepare the reports and oversee all daily operations of this project.

2.2 *Aims*

Occupational slips, trips, and falls on the same level (STF) are one of the leading causes of occupational accidents leading to deaths and injuries across the world. Due to the severity and prevalence of STFs, many researchers have investigated fall risk factors in occupational settings. However, only a handful of studies have investigated the effectiveness of various exercise interventions in reducing falls risks among workers, as most have focused their attention on reducing fall hazards in the work environment. Therefore, the aims of this project were:

1. To have a comprehensive review of the current status of occupational STF injuries in Hong Kong and identify high risk industries and workers for STF;
2. To study existing STF interventions globally;
3. To formulate pragmatic interventions for reducing STF risks with the consideration of HK workplace condition through development of a fall exercise intervention programme to prevent STF;
4. To conduct a pilot study to verify the feasibility of the proposed fall exercise intervention programme;
5. To evaluation the effectiveness of the verified fall exercise intervention programme by a cohort study; and
6. To develop a systematic strategy in promoting the proposed fall exercise interventions programme to workers effectively

2.3 Objectives

Given the aims of this project, our objectives were:

1. To assess the status quo of occupational STF injuries around the globe and in Hong Kong;
2. To perform a thorough literature review to identify the causes of STFs at workplaces;
3. To review and compare various multifaceted and single fall intervention programmes, that can address multiple fall risk factors and specific fall risk factor (e.g. balance / strength issue), and hence identify a few effective fall intervention programmes for evaluation;
4. Based on the above findings, to develop a fall intervention programme including exercise training programme which suits general situation and industries with high STF risk in HK with strong and scientific support to improve the strength and balance of the participants;
5. To conduct a pilot study to verify the feasibility of the fall intervention programme with a focus group which includes workers from general and specific industries;

6. To conduct a cohort study for evaluating the effectiveness of the verified fall intervention programme with a representative sample of the target populations (i.e. general and specific industries);
7. To conduct interviews with industry representatives (construction and catering) to collect opinions on occupational slip, trip and fall accidents among the industries, as well as potential strategies to promote our exercise programme to workers in the future.
8. To recommend suggestions on the Council's strategy to better deliver its overall aims and objectives through promotion, education, consultancy, research and information for the local workforce to cope with occupational STFs, particularly for the ageing workers as they are more prone to STFs.

3 Literature review : Status quo and trends of occupational falls

3.1 Introduction

Fall has been classified as the second leading cause of accidental or unintentional injuries and deaths worldwide by the World Health Organization (2018). It is defined as an “unexpected, uncontrollable and involuntary cause resulting a person to impact on a ground or some lower level” (Hayat & Shan, 2018). Occupational falls can generally be categorised into (1) slip, trip, and fall on same level, or (2) fall from height. Fall-related injuries, including both types of fall, contributed to around 36% of the total workplace injuries in 2021 in Hong Kong, ranking first among all incident types in occupational setting (Labour Department, 2022b). The local fall-related injury rate matches those reported in other parts of the world. Specifically, records have shown that occupational slips, trips and falls have accounted for around 20% to 40% of the total occupational injuries in the United States (Courtney et al., 2001, Yoon & Lockhart, 2006), the United Kingdom (Courtney et al., 2001) and Sweden (Courtney et al., 2001, Kemmlert & Lundolm, 2001). Falls at workplace has caused substantial economic burden on society. In the United States alone, the direct cost caused by falls on same level was estimated at USD\$10.62 billion in 2017, which was ranked second and accounted for 17.7% of the total injury cost. Additionally, fall from height ranked third at USD\$5.5 billion, and accounted for 9.2% of the total injury cost (Liberty Mutual Research Institute for Safety, 2017). Combining both types of fall, the total fall-related injury cost in the United States would amount to USD\$16.12 billion (or 26.9% of the total injury cost), making it the most expensive cause of occupational injuries in the nation. In order to establish the status quo of occupational falls in both Hong Kong and the rest of the world, this 2019 report assessed the data of nine populations, including five in Asia (Hong Kong, Macau, Taiwan, Japan and Singapore) and four in the rest of the world (the U.S., Canada, Australia and Great Britain).

This report disseminated the issue of workplace fall-related statistics in four parts:

1. The status quo and trends of occupational falls in Hong Kong in the past decade;
2. Data of all occupational fall from all population;
3. Data of occupational slip, trip and fall on same level from all populations;
4. Data of occupational fall from height from all populations.

A limitation of this study was that methodologies used to collect fall-related statistics varied among different sources. For instance, only non-fatal accidents with four days absence or more were assessed in Japan (Ministry of Health of Japan, n.d.), whereas only accepted serious claims resulting in a total absence from work of one working week or more were included in Australia (Safe Work Australia, 2022a). Moreover, assorted ordinance, reporting systems and source of statistics also varied among different populations. For example, data of occupational injuries were reported through online reporting system monthly in Taiwan (Occupational Safety and Health Administration of Taiwan, 2022), while work-related accidents are required to be reported by employers or other people in charge of work under RIDDOR within ten days in Great Britain (Health and Safety Executive of Great Britain, 2022) and only accepted serious claims were counted for in Australia (Safe Work Australia, 2022a). As such, even though the data among different populations may not be directly comparable, the data in this report has been interpreted with care, and all the information presented can be considered as reference.

3.2 Occupational falls in Hong Kong

In this section, we examined the data related to all occupational falls in Hong Kong, i.e. including (1) all occupational falls (fatal and non-fatal) combined, as well as separated into (2) non-fatal occupational falls and (3) fatal occupational falls.

3.2.1 All occupational falls (fatal and non-fatal combined) in Hong Kong

According to the statistics from the Labour Department of Hong Kong (2022a, 2022b), total fall incidents, including fatal and non-fatal cases, increased by 5.3% from 30.3% in 2012 to 35.6% in 2021 (Figure 3.1). The incidence rate of slip, trip and fall on same level rose by 6.1% during the same period, contributing to 30% (ranked first) of all types of occupational incidents.



Figure 3.1. Percentage of fatal and non-fatal occupational fall incidents¹ among all types of incidents in Hong Kong from 2012 to 2021 (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b).

¹ Occupational incidents are injury cases arising from work accidents resulting in death or incapacity for work for over three days and are reported under the Employees' Compensation.

3.2.2 Non-fatal occupational falls in Hong Kong

Non-fatal falls, slip, trip and fall on same level incidents, relative to fall from height incidents, were more prevalent in Hong Kong (*Figure 3.2*). Moreover, slip, trip and fall on same level has accounted for the highest proportion of non-fatal occupational incidents (i.e. averaging ~29.9% in the past decade) in Hong Kong (Labour Department of Hong Kong 2022a, 2022b). There appeared to be an increasing trend as the percentage has risen from 26.7% in 2012 to 33.0% in 2021 (i.e. by ~6.3%) (Labour Department of Hong Kong 2022a, 2022b). The number of non-fatal occupational incidents has dropped by 9,526 cases from 39,711 cases in 2012 to 30,185 cases in 2021. Since most occupational falls in Hong Kong were non-fatal, the non-fatal occupational falls statistics presented in the figure below was almost identical to the one presented in the previous section.



Figure 3.2. Percentage of non-fatal occupational fall incidents among all types of non-fatal incidents in Hong Kong from 2012 to 2021 (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b).

The average of non-fatal occupational fall incidence rate was 30.3 per 10,000 workers over the past decade (*Figure 3.3*). Incidence rate of slip, trip and fall on the same level (30.2 per 10,000 workers) was 10 times higher than that of fall from height (3.0 per 10,000 workers).



Figure 3.3. Non-fatal occupational fall incidence rate² per 10,000 workers in all industries in Hong Kong from 2012 to 2021. Annual incidence rates were computed using the number of occupational incidents in Hong Kong from the Labour Department of Hong Kong (2022a, 2022b) and employment size from the Census and Statistics Department of Hong Kong (2022).

² Incidence rate per 10,000 employees is calculated by Number of occupational incidents / Employment size based on the Quarterly Report of Employment and Vacancies Statistics published by the Census and Statistics Department (2022).

3.2.2.1 Non-fatal occupational falls in Hong Kong (by industry)

Looking closer into the incidence rates of occupational falls in different industries, manufacturing sector had the highest incidence rate (average 44.0 per every 10,000 workers; [Figure 3.4](#)) in comparison with other sectors [construction sector: average 37.6 per every 10,000 workers ([Figure 3.5](#)); retail, accommodation and food services sector: 36.7 per every 10,000 workers ([Figure 3.6](#))]. The incidence rate of slip, trip and fall on same level in manufacturing sector also ranked first with 39.4 per every 10,000 workers, followed by 33.7 per every 10,000 workers in retail, accommodation and food services sector. However, the construction sector had the highest incidence rate of fall from height (10.3 per every 10,000 workers) due to their need to work on elevated surfaces frequently. Although the incidence rates of occupational fall in manufacturing sector have been high over the past decade, the trend remained relatively steady.



Figure 3.4. Non-fatal occupational fall incidence rate per 10,000 workers in the manufacturing sector in Hong Kong from 2012 to 2021. Annual incidence rates were computed using the number of occupational incidents in Hong Kong from the Labour Department of Hong Kong (2022a, 2022b) and employment size from the Census and Statistics Department of Hong Kong (2022).

The incidence rate of slip, trip and fall on same level in the construction sector has gradually increased by 2.5 per every 10,000 workers within the past ten years (24.5 per every 10,000 workers in 2012 to 27.0 per every 10,000 workers in 2021), though the incidence rate of fall from height has steadily declined by around 6.0 per every 10,000 workers (13.7 per every 10,000 workers in 2012 to 7.7 per every 10,000 workers in 2021) during the same period (*Figure 3.5*).

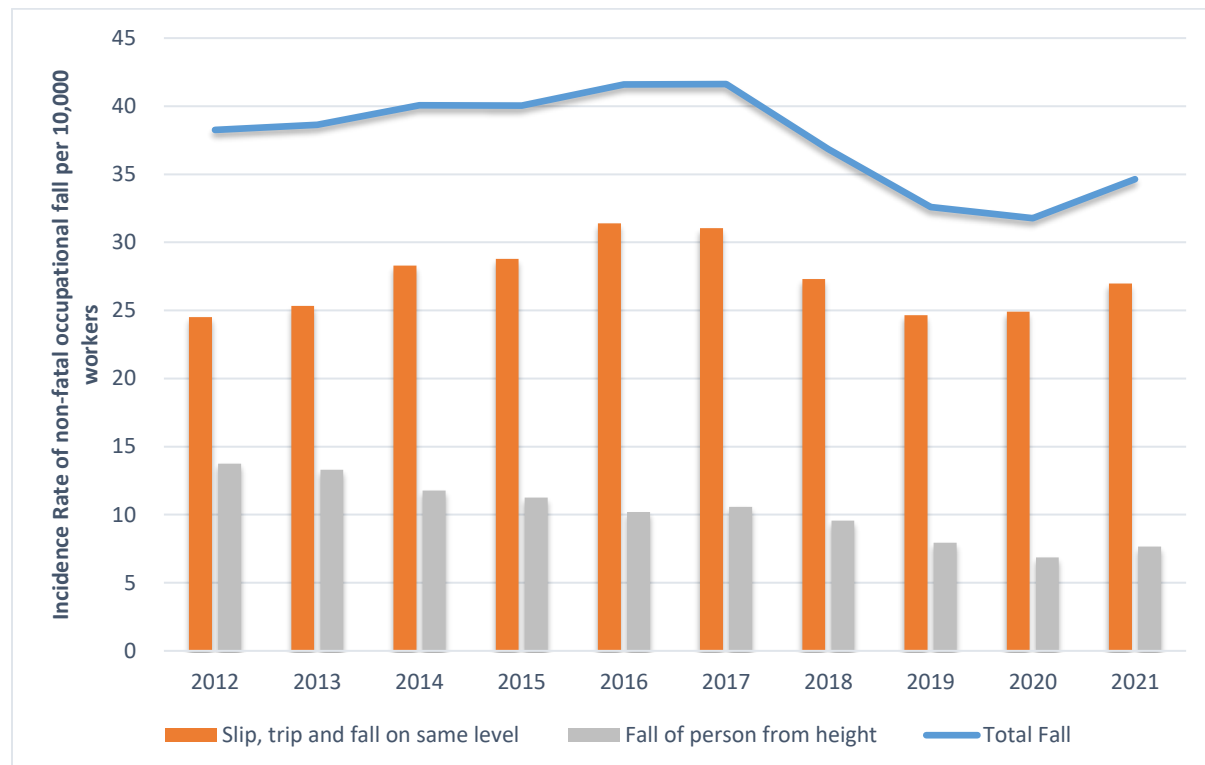


Figure 3.5. Non-fatal occupational fall incidence rate per 10,000 workers in the construction sector in Hong Kong from 2012 to 2021. Annual incidence rates were computed using the number of occupational incidents in Hong Kong from the Labour Department of Hong Kong (2022a, 2022b) and employment size from the Census and Statistics Department of Hong Kong (2022).

The incidence rate of total fall in retail, accommodation and food services sector has decreased modestly by 2.7 per every 10,000 workers (39.6 per every 10,000 workers in 2012 and 36.9 per every 10,000 workers in 2021), also the rate of slip, trip and fall on same level has declined by 1.6 per every 10,000 workers (36.0 per every 10,000 workers in 2012 and 34.4 per every 10,000 workers in 2021) over the past decade ([Figure 3.6](#)).



Figure 3.6. Non-fatal occupational fall incidence rate per 10,000 workers in the retail, accommodation and food services sector in Hong Kong from 2012 to 2021. Annual incidence rates were computed using the number of occupational incidents in Hong Kong from the Labour Department of Hong Kong (2022a, 2022b) and employment size from the Census and Statistics Department of Hong Kong (2022).

3.2.3 Fatal occupational falls in Hong Kong

Unsurprisingly, fall from height had accounted for almost 99% of all fatal occupational falls in Hong Kong in the past decade (*Figure 3.7*), since slip, trips and falls on same level rarely resulted in fatality.



Figure 3.7. Percentage of fatal occupational fall incidents among all types of fatal incidents in Hong Kong from 2012 to 2021 (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b).

In terms of incidence rate, an average of 7.2 fatal falls from height per 1,000,000 workers has been recorded in the past 10 years with no apparent trend of increase nor decrease (*Figure 3.8*).



Figure 3.8. Fatal occupational fall incidence rate per 1,000,000 workers in all Industry in Hong Kong from 2012 to 2021. Annual incidence rates were computed using the number of occupational incidents in Hong Kong from the Labour Department of Hong Kong (2022a, 2022b) and employment size from the Census and Statistics Department of Hong Kong (2022).

3.3 All occupational falls

In this section, we examined the data related to all occupational falls, i.e. including (1) slip, trip, and fall on same level, as well as (2) fall from height in Hong Kong relative to other populations.

3.3.1 All occupational falls (fatal and non-fatal combined)

In Hong Kong, an average of 32.9% of all occupational incidences were fall-related in the past decade, which was ranked third behind Japan (39.6%) and Great Britain (38.1%), and ahead of Singapore (31.8%), Taiwan (25.2%), the United States (24.7%), Macau (21.4%), Australia (20.7%) and Canada (17.9%; [Table 3.1](#)).

Table 3.1. Percentage of fatal and non-fatal occupational falls incidents among all incidents in H.K. and other populations from 2012 to 2021.

Populations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Japan	38.7 %	39.0 %	39.8 %	39.4 %	40.0 %	40.4 %	41.7 %	40.9 %	39.6 %	36.7 %	39.6%
Great Britain	N/A	N/A	35.9 %	36.0 %	36.0 %	38.2 %	36.4 %	43.3 %	40.5 %	38.6 %	38.1%
Hong Kong	30.3 %	31.2 %	31.8 %	32.2 %	34.0 %	33.1 %	32.8 %	32.9 %	35.2 %	35.6 %	32.9%
Singapore	N/A	28.2 %	28.8 %	29.9 %	31.9 %	33.0 %	33.3 %	33.3 %	34.5 %	33.7 %	31.8%
Taiwan	22.2 %	23.1 %	22.6 %	24.9 %	25.4 %	26.0 %	25.6 %	27.8 %	27.0 %	27.6 %	25.2%
United State	21.6 %	24.3 %	26.3 %	25.9 %	24.9 %	25.3 %	N/A	N/A	N/A	N/A	24.7%
Macau	N/A	17.6 %	22.2 %	20.6 %	21.5 %	21.2 %	21.1 %	22.9 %	21.7 %	24.0 %	21.4%
Australia ³	20.3 %	19.9 %	20.2 %	20.7 %	20.5 %	21.2 %	21.1 %	20.8 %	21.3 %	N/A	20.7%
Canada	16.7 %	17.9 %	18.4 %	17.9 %	17.7 %	18.6 %	18.4 %	19.2 %	16.3 %	N/A	17.9%

Note: Data were retrieved from the following sources: Hong Kong 2012-2021: (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b); Japan 2012-2021: (Ministry of Health of Japan, n.d.), the Great Britain 2014-2021: (Health and Safety Executive of the Great Britain, 2022), Singapore 2013-2021: (Ministry of Manpower of Singapore, 2022a), the United States 2012-2017: (Bureau of Labor Statistics of the U.S., 2018c), Taiwan

³ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Australia 2012-2020: (Safe Work Australia, 2022a, Safe Work Australia, 2022b), Macau 2013-2021: (The Labour Affairs Bureau of Macau, 2022), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.)

3.3.2 Non-fatal falls

Excluding the fatal occupational falls, an average of 33.0% of all non-fatal occupational incidents resulted from a fall in Hong Kong over the past 10 years ([Table 3.2](#)). The average percentages of non-fatal occupational falls among all non-fatal incidents were similar to those presented in [Table 3.1](#), as majority of occupational falls were non-fatal.

Table 3.2. Percentage of non-fatal occupational falls incidents among all non-fatal incidents in H.K. and other populations from 2012 to 2021.

Populations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Japan	38.8 %	39.1 %	39.9 %	39.5 %	40.2 %	40.5 %	41.7 %	41.0 %	39.7 %	36.7 %	39.7%
Great Britain	N/A	N/A	35.9 %	36.0 %	36.0 %	38.2 %	36.4 %	43.3 %	40.5 %	38.6 %	38.1%
Hong Kong	30.4 %	31.2 %	31.9 %	32.3 %	34.1 %	33.3 %	32.9 %	33.1 %	35.4 %	35.8 %	33.0%
Singapore	N/A	28.2 %	28.8 %	29.8 %	31.9 %	33.0 %	33.3 %	33.3 %	34.5 %	33.8 %	31.9%
Taiwan	22.2 %	23.1 %	22.7 %	25.1 %	25.7 %	26.0 %	25.8 %	28.0 %	27.1 %	27.8 %	25.4%
United State	21.6 %	24.3 %	26.4 %	25.9 %	25.0 %	25.3 %	N/A	N/A	N/A	N/A	24.8%
Macau	N/A	17.6 %	22.2 %	20.3 %	21.6 %	21.3 %	21.0 %	22.9 %	21.7 %	24.0 %	21.4%
Australia ⁴	20.3 %	19.9 %	20.3 %	20.7 %	20.5 %	21.2 %	21.1 %	20.8 %	21.3 %	N/A	20.7%
Canada	16.8 %	17.9 %	18.5 %	17.9 %	17.7 %	18.7 %	18.4 %	19.2 %	16.3 %	N/A	17.9%

Note: Data were retrieved from the following sources: Hong Kong 2012-2021: (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b); Japan 2012-2021: (Ministry of Health of Japan, n.d.), the Great Britain 2014-2021: (Health and Safety Executive of the Great Britain, 2022), Singapore 2013-2021: (Ministry of Manpower of Singapore, 2021), the United States 2012-2017: (Bureau of Labor Statistics of the U.S., 2018c), Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Australia 2012-2020: (Safe Work Australia, 2022a), Macau 2013-2021: (The Labour Affairs Bureau of Macau, 2022), Canada: (Association of Workers' Compensation Boards of Canada, n.d.)

⁴ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

According to the statistic reported by the Labour Department of Hong Kong (2022a, 2022b), Hong Kong averaged the highest non-fatal occupational falls incidence rate (i.e. 30.2 per 10,000 workers) among other populations, such as Canada (24.7 per 10,000 workers), Australia (19.7 per every 10,000 workers), the United States (19.6 per 10,000 workers), Singapore (11.5 per every 10,000 workers), and Taiwan (average 7.5 per 10,000 workers; [Figure 3.9](#)).

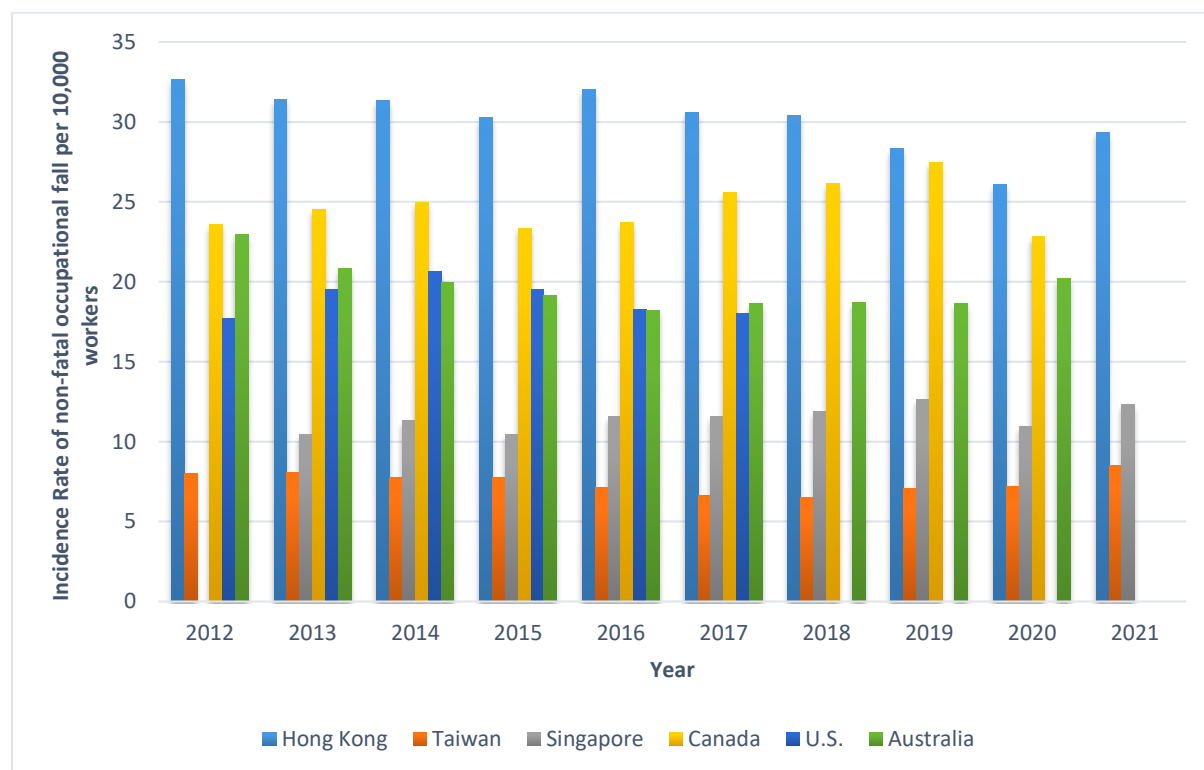


Figure 3.9. Non-fatal occupational falls incidence rate per 10,000 workers in all industries in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Singapore 2013-2021: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022b), Canada: (Association of Workers' Compensation Boards of Canada, n.d.; Statistics Canada, n.d.), the United States⁵ 2012-2017: (Bureau of Labor Statistics of U.S., 2018c), Australia⁶: (Australian Bureau of Statistics, 2022; Safe Work Australia, 2022a)] from 2012 to 2022.

⁵ STF on same level including the categories of Fall on same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018c).

⁶ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

3.3.2.1 All non-fatal occupational fall (by Industry)

Hong Kong has reported the highest non-fatal occupational fall incidents rate in the manufacturing (average 44.0 per 10,000 workers) and construction sectors (average 37.6 per 10,000 workers) among Taiwan, Japan and the United State. However, the rate of retail, accommodation and food service sector could not be computed among the different populations due to the unavailability of relevant statistics, such as the number of incidents and employment size in many of the other populations. Incidence rate of non-fatal occupational fall in manufacturing sector in Hong Kong (*Figure 3.10*) was 7.1 times higher than that of Taiwan (average 6.2 per 10,000 workers), 5.9 times higher than that of Japan (average 7.5 per 10,000 workers) and 2.5 times higher than that of the United States (average 17.9 per 10,000 workers).

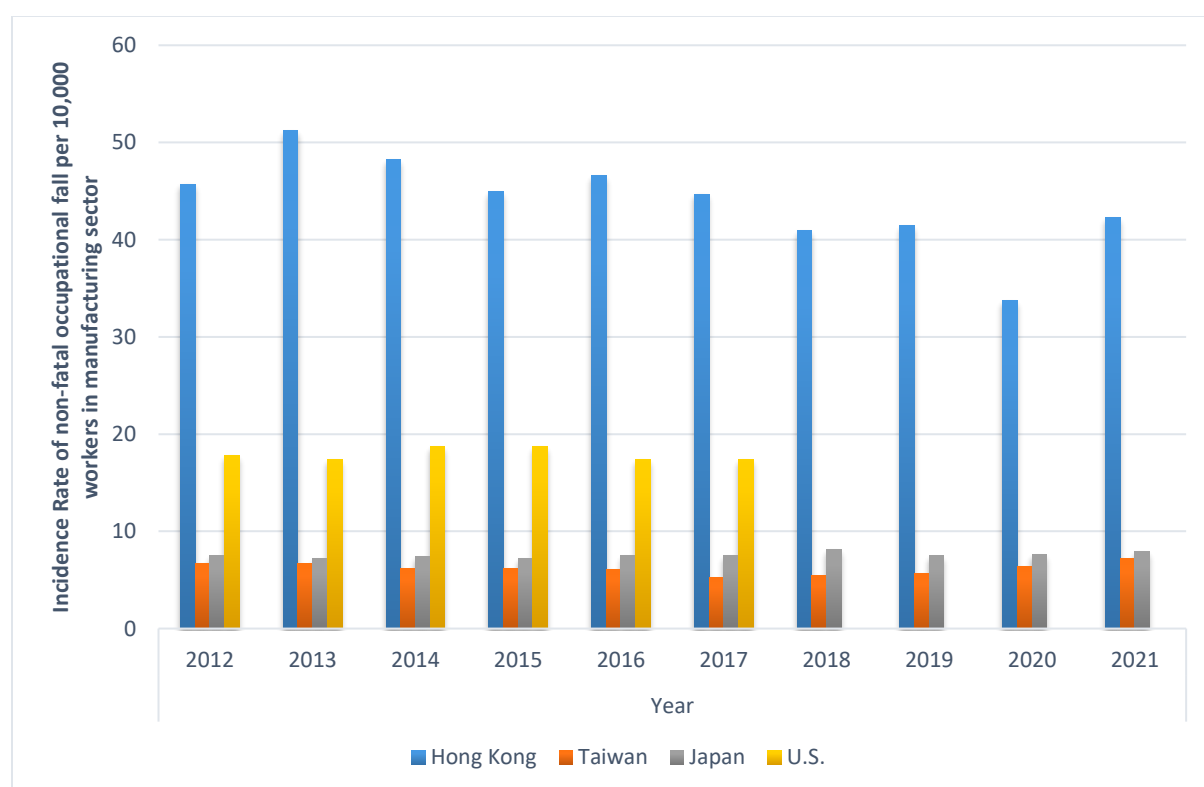


Figure 3.10. Non-fatal occupational falls incidence rate per 10,000 workers in the manufacturing sector in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Japan 2012-2021: (Ministry of Health of Japan, n.d.), the United States⁷ 2012-2017: (Bureau of Labor Statistics of the U.S., 2018c)] from 2012 to 2021.

⁷ STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018c).

In the construction sector, Hong Kong (average 37.6 per 10,000 workers) and the United States (average 34.7 per 10,000 workers) have reported the highest average incidence rates of non-fatal occupational falls among the other populations (*Figure 3.11*). Relative to other Asian populations, Hong Kong's non-fatal occupational fall incidence rate was 3.5 times higher than that of Taiwan (average 10.7 per 10,000 workers) and 2.7 times higher than that of Japan (average 13.7 per 10,000 workers).

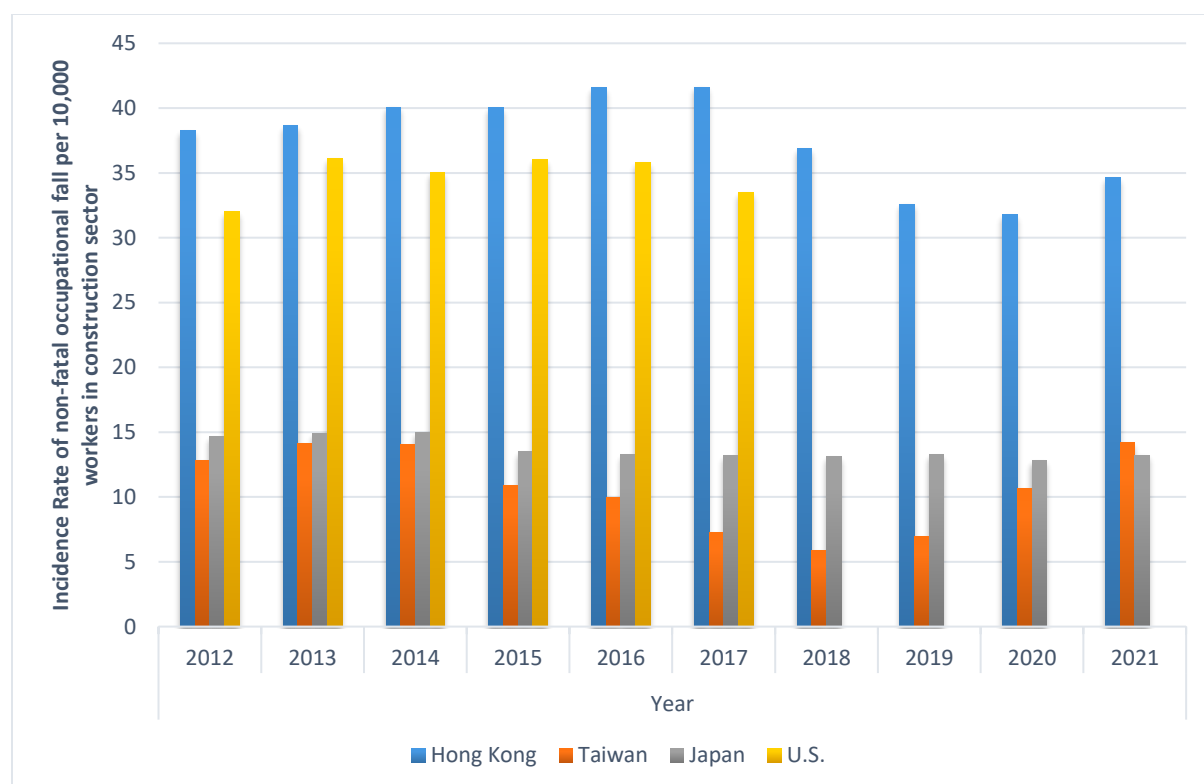


Figure 3.11. Non-fatal occupational falls incidence rate per 10,000 workers in the construction sector in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Japan 2012-2021: (Ministry of Health of Japan, n.d.), the United States⁸ 2012-2017: (Bureau of Labor Statistics of the U.S., 2018c)] from 2012 to 2021.

⁸ STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018c).

3.3.2.2 Non-fatal occupational fall (by gender)

Incidence rate of non-fatal occupational falls of the two genders has not been addressed in Hong Kong. Nonetheless, according to the Bureau of Labor Statistics of the United States (2018a, 2018b), the women's incidence rates of non-fatal occupational falls have been consistently higher than that of the men's (mean difference = 5.7 per 10,000 full-time workers) from 2011 to 2017 (*Figure 3.12*).

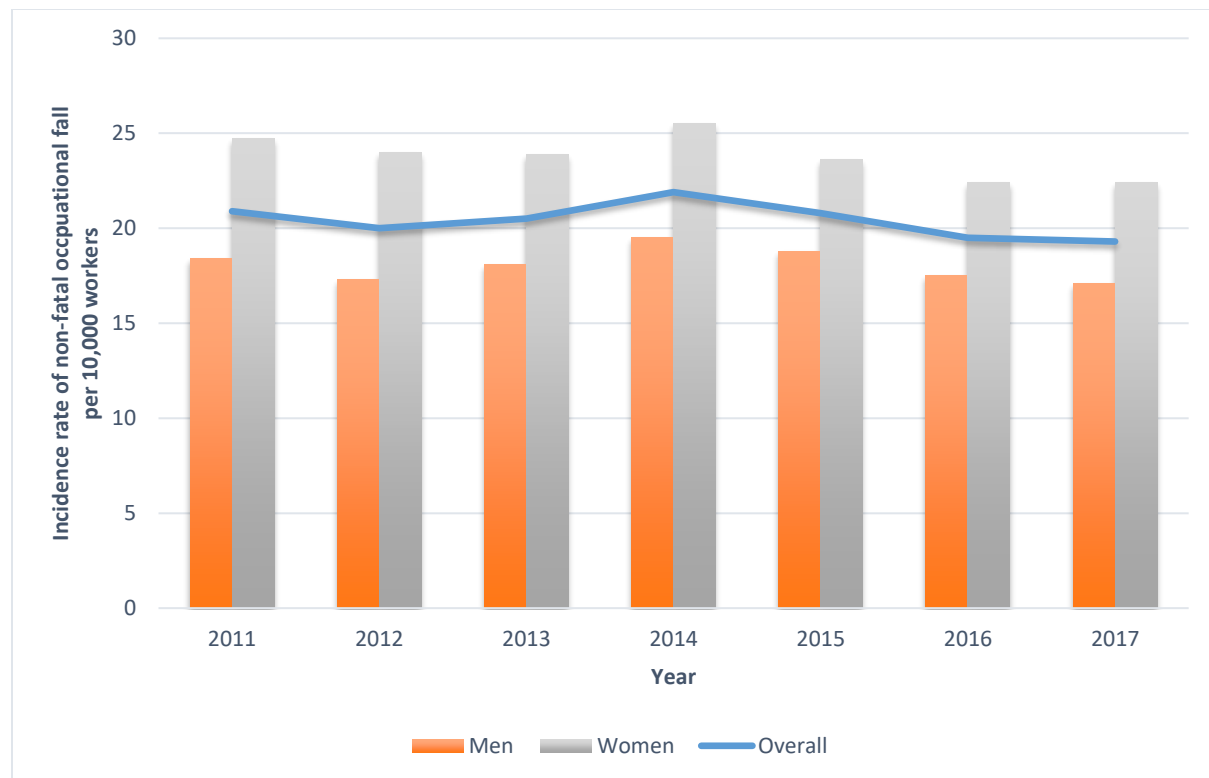


Figure 3.12. Non-fatal occupational falls incidence rate per 10,000 workers by gender in the United States from 2011 to 2017 (Bureau of Labor Statistics of the U.S., 2018a; Bureau of Labor Statistics of the U.S., 2018b).

3.3.2.3 Non-fatal occupational fall (by age)

Fall incidence rate of the different age groups has not been reported for the Hong Kong working population. Referring to the figures reported by the Bureau of Labor Statistics of the United States (2018a, 2018b), the oldest working age-group (i.e. 65 and over) had the highest incidence rate of non-fatal occupational falls injuries (average 38.2 per 10,000 full-time workers), followed by the second oldest age group of 55 to 64 (average 32.2 per 10,000 full-time workers) and the third oldest age group of 45 to 54 (average 23.1 per 10,000 full time workers) in 2011-2017 (*Figure 3.13*). Therefore, it is apparent that age is a risk factor for increased occupational fall risk (Bureau of Labor Statistics of the U.S., 2018a, 2018b).

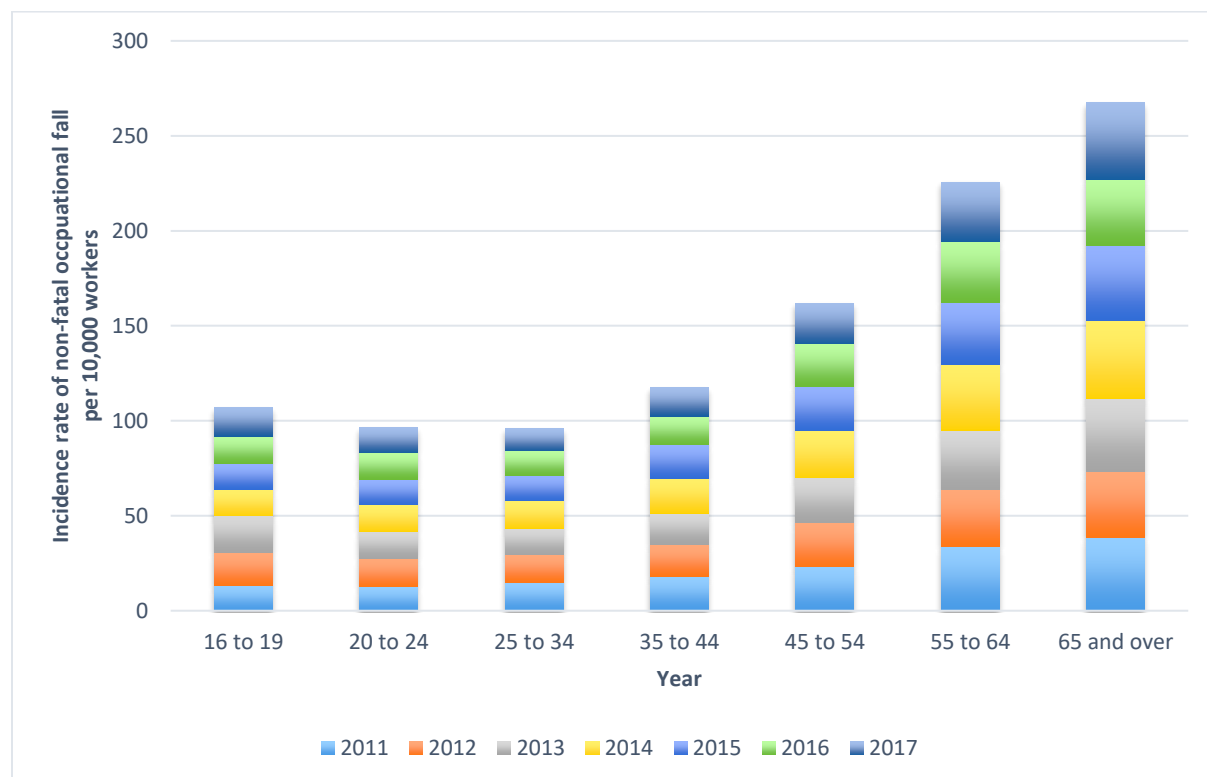


Figure 3.13. Non-fatal occupational falls incidence rate per 10,000 workers by age in the United States from 2011 to 2017 (Bureau of Labor Statistics of the U.S., 2018a, Bureau of Labor Statistics of the U.S., 2018b).

3.3.3 Fatal occupational fall

In Hong Kong, only 10.4% of all fatal occupational incidents were fall-related over the past 10 years, which was similar to the figures presented in Australia (13.2%; [Table 3.3](#)). Only Canada (6.8%) has reported fewer percentage of fall-related fatality in occupational settings. Comparatively, Singapore (29.4%), Japan (28.4%), Great Britain (27.2%), Macau (21.3%), Taiwan (20.9%) and the United States (16.4%) have reported higher percentages than in Hong Kong.

Table 3.3. Percentage of fatal occupational falls incidents among all fatal incidents in H.K. and other populations from 2012 to 2021.

Populations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Singapore	N/A	23.3%	23.3%	34.8%	28.8%	28.6%	36.6%	25.6%	36.7%	27.0%	29.4%
Japan	27.8%	29.1%	26.9%	29.0%	27.6%	28.6%	31.2%	28.4%	27.3%	28.0%	28.4%
Great Britain	N/A	N/A	31.0%	25.9%	22.2%	27.7%	30.2%	29.2%	26.9%	24.4%	27.2%
Macau	N/A	5.3%	33.3%	24.0%	14.8%	10.5%	41.7%	28.6%	7.1%	26.7%	21.3%
Taiwan	21.5%	22.6%	19.8%	21.8%	19.7%	25.1%	19.3%	22.9%	18.5%	18.1%	20.9%
United State	15.2%	15.8%	17.0%	16.5%	16.4%	17.2%	N/A	N/A	N/A	N/A	16.4%
Australia⁹	14.7%	12.9%	11.7%	14.2%	13.9%	15.7%	11.8%	11.1%	12.4%	N/A	13.2%
Hong Kong	15.8%	17.6%	11.0%	9.0%	9.4%	11.9%	9.2%	6.8%	5.6%	7.6%	10.4%
Canada	5.8%	7.2%	6.9%	6.8%	7.3%	6.3%	6.2%	7.9%	6.4%	N/A	6.8%

Note: Data were retrieved from the following sources: Hong Kong 2012-2021: (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b); Singapore 2013-2021: (Ministry of Manpower of Singapore, 2022a); Japan 2012-2021: (Ministry of Health of Japan, n.d.); Great Britain 2014-2021 (Health and Safety Executive of Great Britain, 2022); Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022); Macau 2013-2021: (The Labour Affairs Bureau of Macau, 2022); the United States 2012-2017: (Bureau of Labor Statistics of the U.S., 2018c); Australia 2012-2020: (Safe Work Australia, 2022b); Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.).

⁹ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

3.3.4 Time lost to work due to fall

The statistics of time lost to work due to fall-related incidents has not been reported in Hong Kong; however, Safe Work Australia (2022a) has shown that the median time lost to work due to all types of fall (average 6.3 working weeks) was slightly higher than the overall median time lost to work due to various other reasons (average 5.6 working weeks). Unsurprisingly, workers on average took longer time to recover from falls from height (7.4 working weeks) than falls on same level (5.8 working weeks; *Figure 3.14*).

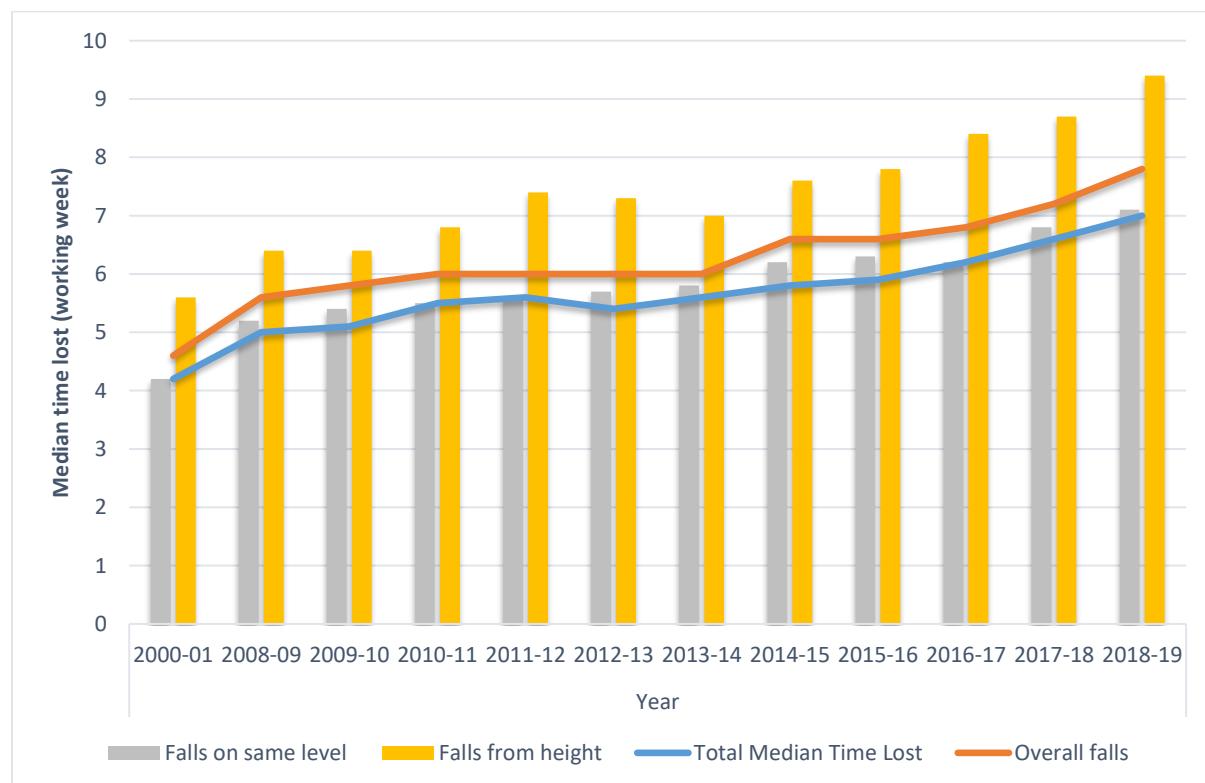


Figure 3.14. Median time lost by falls, trips and slips of a person in Australia from 2000-01 to 2018-19 (Safe Work Australia, 2022a).

3.3.5 Compensation

Similarly, data on the compensation for fall-related incidents in Hong Kong could not be found. According to Safe Work Australia (2022a), the median compensation paid for fall-related incidents averaged out to be AUD\$ 10,983.3, which was higher than the average total compensation paid for all type of causes (AUD\$ 10,433.3). Due to the more serious consequences resulted from falls from height, the average compensation paid for such type of fall (AUD\$ 13,433.3) was higher than for falls on same level (AUD\$ 10,175) from 2000-01 to 2018-19 (Figure 3.15).

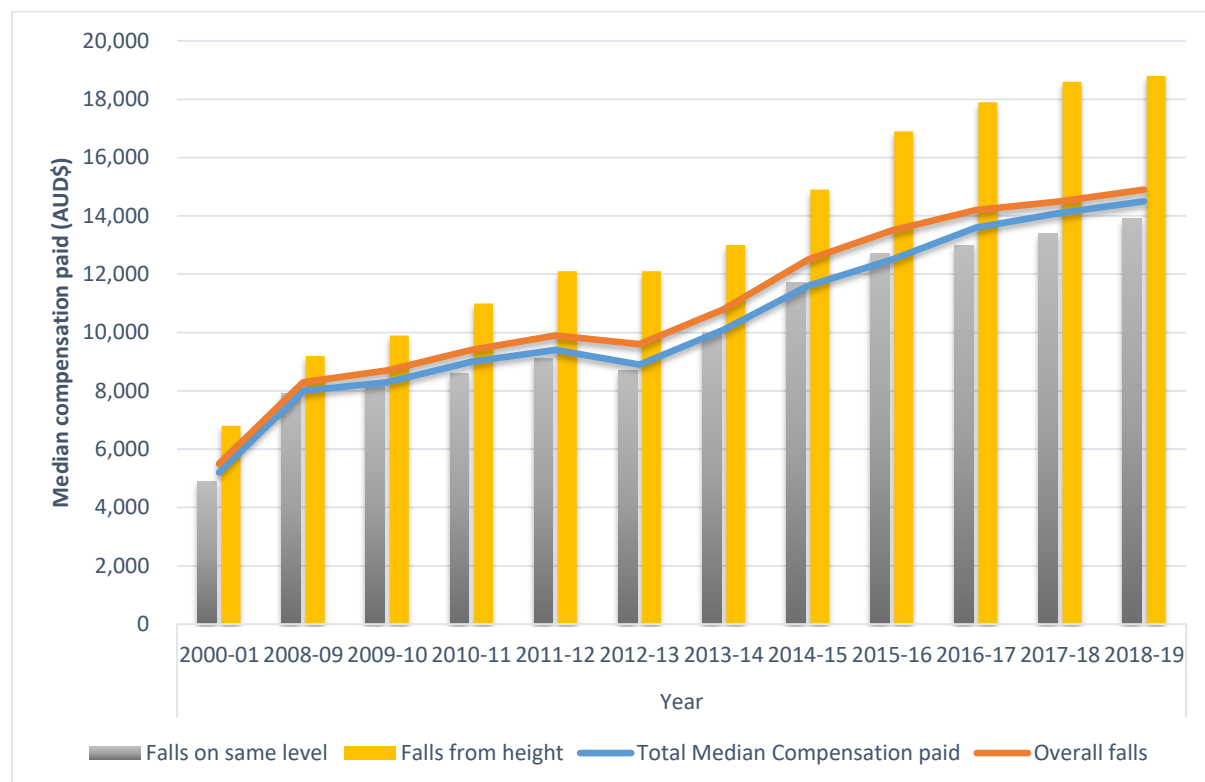


Figure 3.15. Median compensation paid by falls, trips and slips of a person in Australia from 2000-01 to 2018-19 (Safe Work Australia, 2022a).

According to the National Council on Compensation Insurance from the United States (2022), the total incurred costs per claim caused by fall or slip (USD\$ 48,575) ranked third among all sorts of claims. Moreover, the average fall-related compensation was above than the overall claims average of USD\$ 41,353 (*Figure 3.16*).

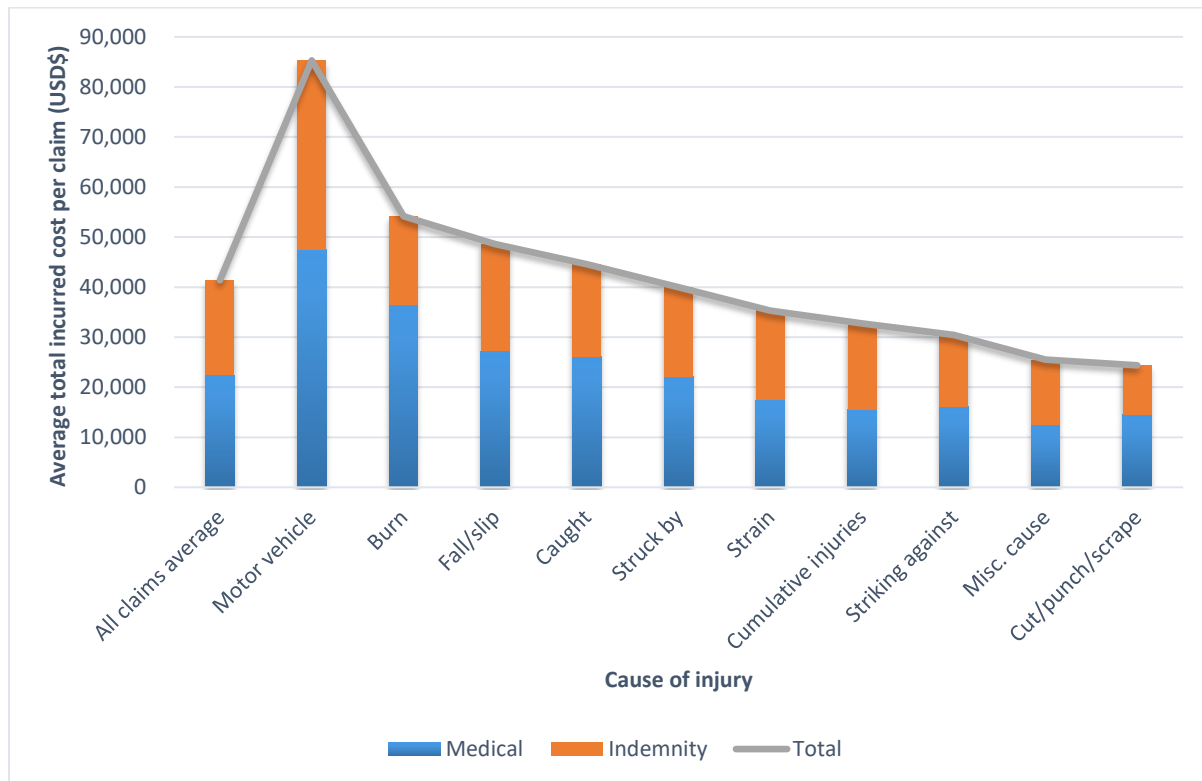


Figure 3.16. Average total incurred costs per claim by cause of injury in the United States, 2019-2020 (National Council on Compensation Insurance of the U.S, 2022).

3.4 Occupational slip, trip, and falls on same level (STF)

In this section, we examined the data related to all occupational STF, i.e. including (1) all occupational STF, (2) non- fatal occupational STF as well as (3) fatal occupational STF.

3.4.1 All occupational slip, trip and fall on same level (fatal & non-fatal combined)

Referring to the statistic released by the Labour Department (2022a, 2022b), Hong Kong had the highest occupational STF incidents rate per 10,000 workers among other Asian populations such as Taiwan (O, 2022) and Singapore (Ministry of Manpower of Singapore, 2022a), as well as among other countries such as Canada (Association of Workers' Compensation Boards of Canada, n.d.) and Great Britain (Health and Safety Executive of Great Britain, 2022; *Figure 3.17*).

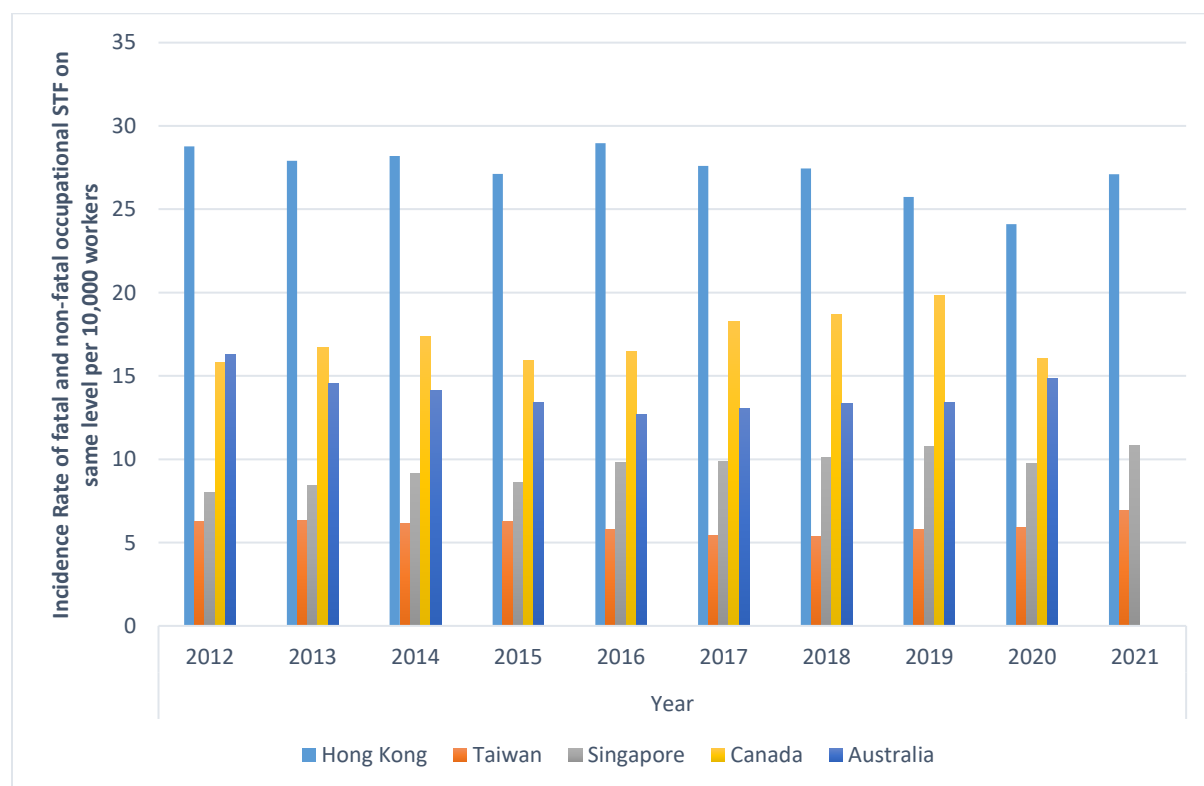


Figure 3.17. Fatal and non-fatal occupational slip, trip and fall on same level incidence rate per 10,000 workers in all industry in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Singapore 2012-2021: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022b), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.; Statistics Canada, n.d.), Australia¹⁰ 2012-2021: (Australian Bureau of Statistics, 2022; Safe Work Australia, 2018a; Safe Work Australia, 2018b)] from 2012 to 2021.

¹⁰ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

3.4.2 Non-fatal occupational slip, trip and fall on same level

In comparison to other populations for the past three years, slip, trip and fall on same level in Hong Kong has accounted for higher percentage of total non-fatal incidents than Taiwan, Singapore, Macau, Japan, Canada, the United States and Australia ([Table 3.4](#)). In addition, there seemed to be an increasing trend in two (Hong Kong and Singapore) of the nine populations.

Table 3.4. Percentage of non-fatal occupational slip, trip and fall on same level incidents among all non-fatal incidents in H.K. and other populations from 2012 to 2021.

Populations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Great Britain	N/A	N/A	28.2 %	28.2 %	28.5 %	30.5 %	28.8 %	34.0 %	32.4 %	30.4 %	30.1%
Hong Kong	26.7 %	27.7 %	28.7 %	28.9 %	30.9 %	30.0 %	29.7 %	30.1 %	32.7 %	33.0 %	29.9%
Singapore	N/A	22.6 %	23.0 %	24.4 %	26.8 %	28.0 %	28.2 %	28.4 %	30.6 %	29.6 %	26.8%
Japan	21.7 %	21.9 %	22.6 %	22.3 %	23.0 %	23.5 %	25.0 %	23.9 %	23.6 %	22.5 %	23.0%
United States	16.5 %	19.2 %	21.0 %	20.3 %	19.6 %	20.0 %	N/A	N/A	N/A	N/A	19.4%
Macau	N/A	14.9 %	17.8 %	16.7 %	17.5 %	17.8 %	17.4 %	19.2 %	17.1 %	18.7 %	17.4%
Australia ¹¹	14.4 %	13.9 %	14.3 %	14.4 %	14.3 %	14.8 %	15.0 %	14.9 %	15.6 %	N/A	14.6%
Canada	11.2 %	12.1 %	12.8 %	12.2 %	12.3 %	13.3 %	13.1 %	13.9 %	11.4 %	N/A	12.5%
Taiwan	9.4%	9.1%	8.7%	8.4%	9.2%	9.4%	9.5%	9.4%	9.2%	8.7%	9.1%

Note: Data were retrieved from the following sources: Hong Kong 2012-2021: (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b); the Great Britain 2014-2021: (Health and Safety Executive of the Great Britain, 2022), Singapore 2013-2021: (Ministry of Manpower of Singapore, 2022a), Japan 2012-2021: (Ministry of Health of Japan, n.d.), the United States 2012-2017: (Bureau of Labor Statistics of the U.S., 2018c), Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Macau 2013-2021: (The Labour Affairs Bureau of Macau, 2022), Australia 2012-2020: (Safe Work Australia, 2022a), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.)

¹¹ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

The average incidence rate of occupational slip, trip and fall in Hong Kong (27.3 per every 10,000 workers) ranked first among six different populations (i.e. Hong Kong, Taiwan, Singapore, Canada, the United States and Australia) in 2012-2021 (*Figure 3.18*). It was significantly higher than other Asian [i.e. 4.6 times higher than Taiwan (6.0 per every 10,000 workers) and 2.9 times higher than Singapore (9.5 per every 10,000 workers)] and western populations [around 1.6 to 2.0 times higher than the rate of Australia (14.0 per every 10,000 workers), the United States (15.1 per every 10,000 workers) and Canada (17.2 per every 10,000 workers)].

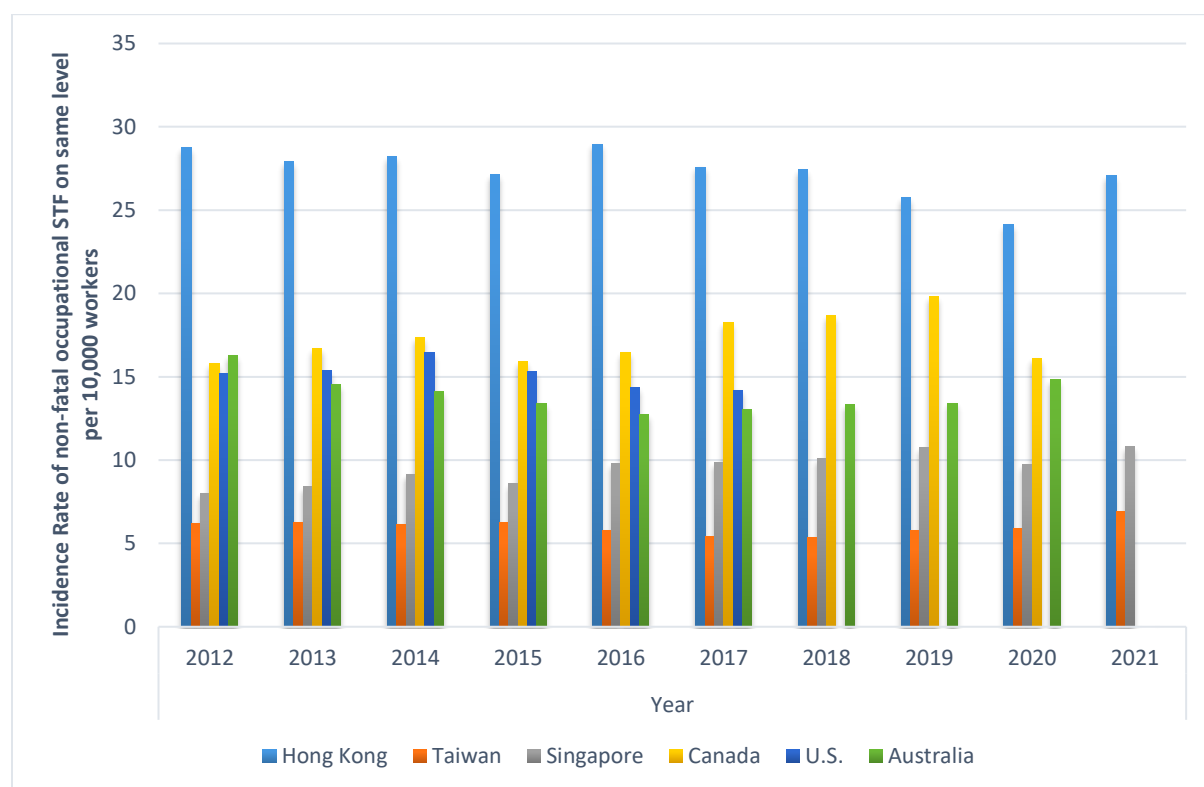


Figure 3.18. Non-fatal occupational slip, trip and fall incidence rate per 10,000 workers in all industries in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Singapore 2012-2021: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022b), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.; Statistics Canada, n.d.), the United States¹² 2012-2017: (Bureau of Labor Statistics of U.S., 2018c), Australia¹³ 2012-2021: (Australian Bureau of Statistics, 2022; Safe Work Australia, 2018a; Safe Work Australia, 2018b)] from 2012 to 2021.

¹² STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018c).

¹³ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

3.4.2.1 Non-fatal occupational slip, trip and fall on same level (by Industry)

As mentioned in section 4.2.2.1, the highest fall incidence rate in Hong Kong was observed in the manufacturing industry over the past decade. The average incidence rate of non-fatal occupational slip, trip and fall on same level was 40.4 per 10,000 workers in the manufacturing sector in Hong Kong, which was almost 8.5 times higher than that of Taiwan (4.8 per every 10,000 workers) and Japan (4.7 per every 10,000 workers). Such average incidence rate was also 2.8 times higher than that of the United States (14.2 per every 10,000 workers; [Figure 3.19](#)).

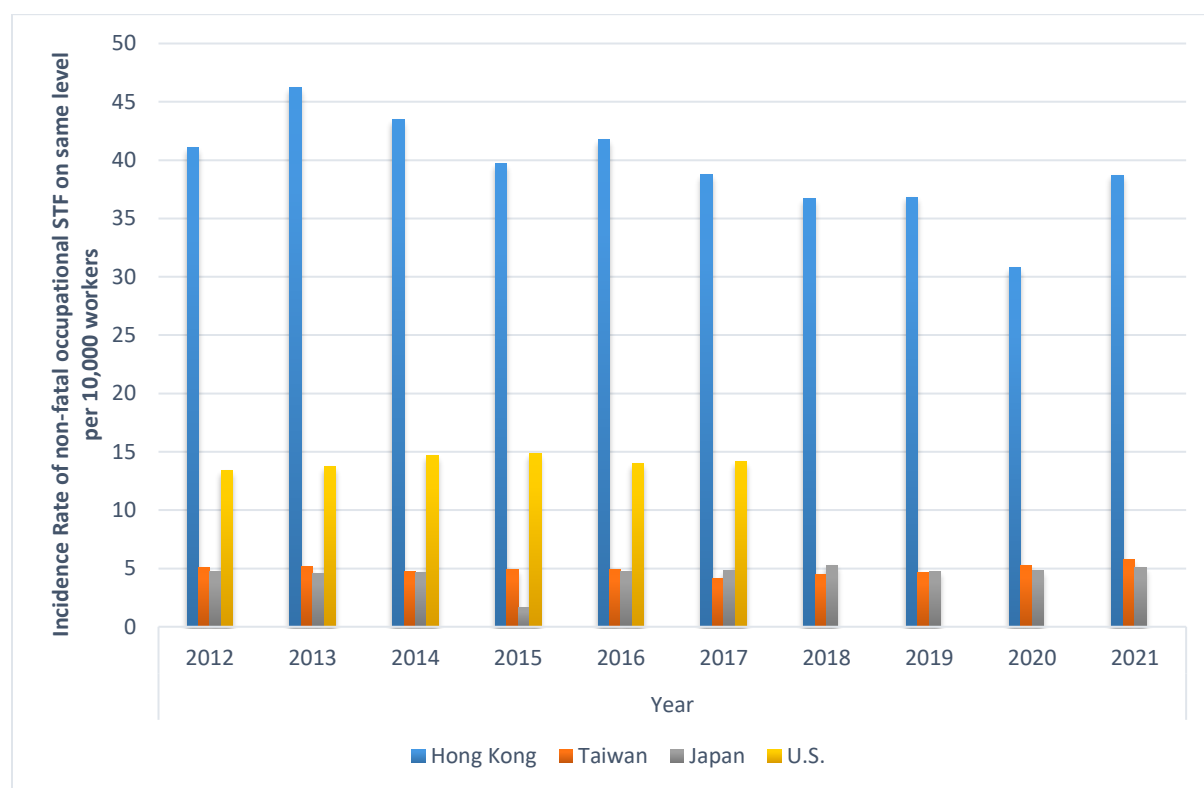


Figure 3.19. Non-fatal occupational slip, trip and fall on same level incidence rate per 10,000 workers in the manufacturing sector in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Japan 2012-2021: (Ministry of Health of Japan, n.d.), the United States¹⁴ 2012-2017: (Bureau of Labor Statistics of the U.S., 2018c)] from 2012 to 2021.

¹⁴ STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018c).

Besides the manufacturing sector, construction sector had the second highest non-fatal slip, trip and fall on same level incidence rate in Hong Kong (i.e. 25-31 per 10,000 workers injured in 2012-2021). The average incidence rate over the past decade was 27.3 per 10,000 workers, which was 8 times higher than Japan, 1.5 times higher than Taiwan and twice of that of the United States (Figure 3.20).

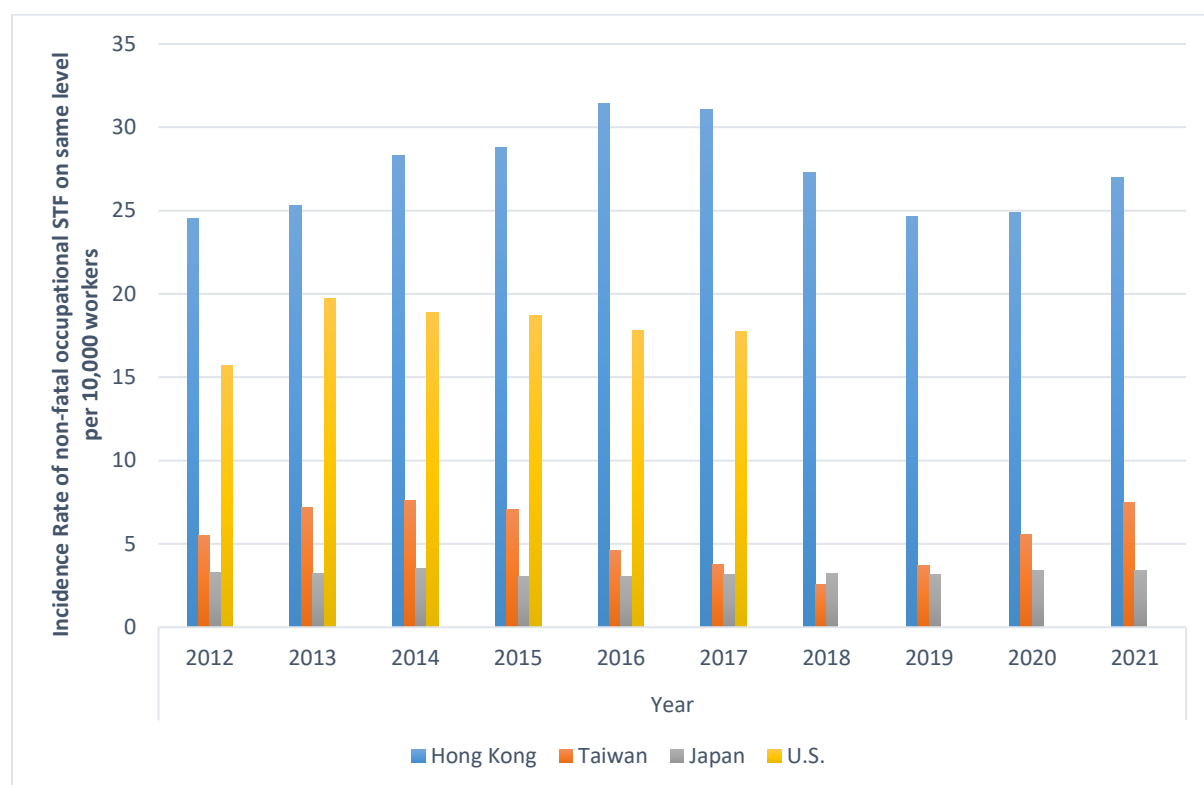


Figure 3.20. Non-fatal occupational slip, trip and fall on same level incidence rate per 10,000 workers in the construction sector in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Japan 2012-2021: (Ministry of Health of Japan, n.d.), the United States¹⁵ 2012-2017 (Bureau of Labor Statistics of the U.S., 2018c)] from 2012 to 2021.

¹⁵ STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018c).

3.4.2.2 Non-fatal occupational slip, trip and fall on same level (by gender)

Incidence rate of non-fatal occupational slip, trip and fall on same level of the two genders has not been reported in Hong Kong. Nevertheless, as reported by the Bureau of Labor Statistics of the United States (2018b), the women incidence rate of non-fatal occupational fall on same level injuries has been consistently higher than that of the men's (mean difference = 9.5 per 10,000 full-time workers) from 2011 to 2017 (*Figure 3.21*).



Figure 3.21. Non-fatal occupational fall on same level incidence rate per 10,000 workers by gender in the United States from 2011 to 2017 (Bureau of Labor Statistics of the U.S., 2018b).

3.4.2.3 Non-fatal occupational slip, trip and fall on same level (by age)

Similarly, fall incidence rate in different age group could not be computed for the Hong Kong working population. Using data obtained from the United States (Bureau of Labor Statistics of the U.S., 2018a), it has been found that senior workers aged 65 and over had the highest incidence rate of non-fatal occupational fall on same level injuries (average 31.9 per 10,000 full-time workers), followed by the second oldest age group of 55 to 64 (average 25.6 per 10,000 full-time workers) and the third oldest age group of 45 to 54 (average 17.1 per 10,000 full time workers) in 2011-2017 ([Figure 3.22](#)). Therefore, age is definitely a significant risk factor for increased occupational fall risk (Bureau of Labor Statistics of the U.S., 2018a). With an aging working population in Hong Kong (Census and Statistics Department 2022; [Figure 3.23](#)), the overall occupational fall incident rate is expected to climb over the coming years.

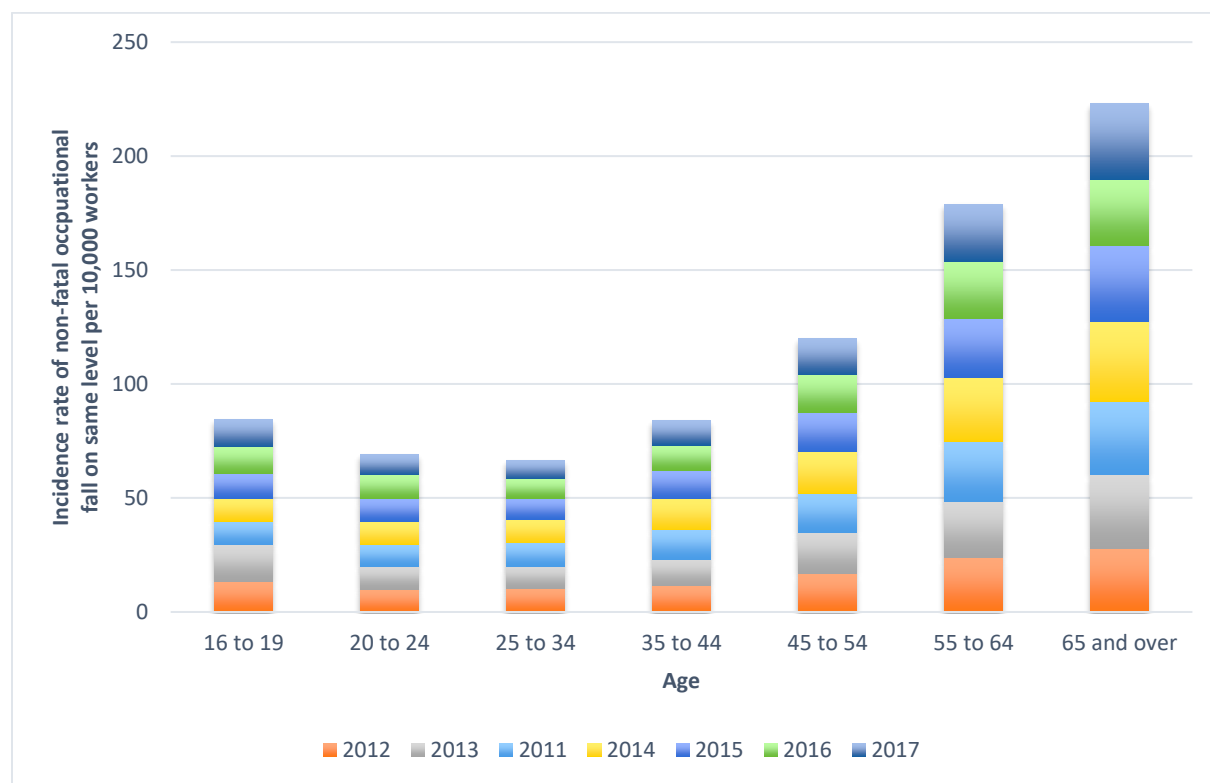


Figure 3.22. Non-fatal occupational fall on same level incidence rate per 10,000 workers by age in the United States from 2011 to 2017 (Bureau of Labor Statistics of the U.S., 2018b).

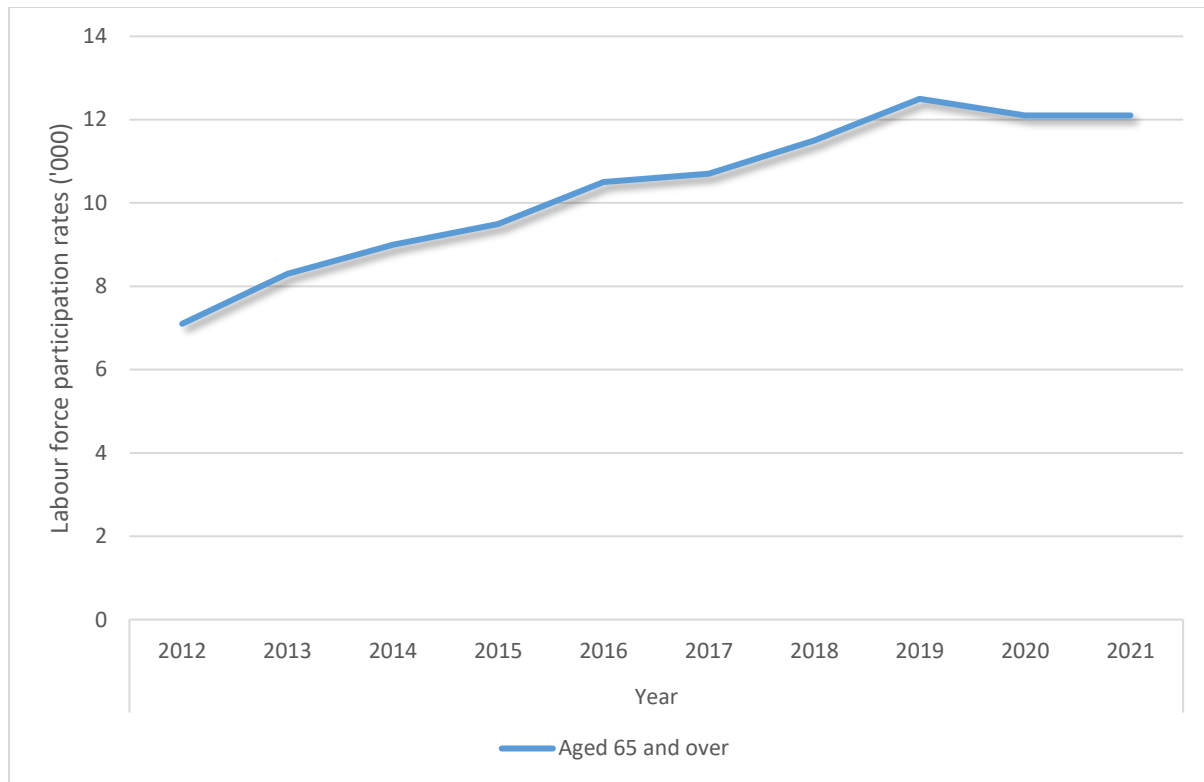


Figure 3.23. Labour force participation rates of aged 65 and over in Hong Kong from 2012- 2021 (Census and Statistics Department, 2022).

3.4.2.4 Non-fatal occupational slip, trip and fall on same level (by injured body location)

The data of injured body location has not been addressed in Hong Kong. Referring to the statistics provided by the Occupational Safety and Health Administration of Taiwan (2022; [Figure 3.24](#)), Safe Work Australia (2022a; [Figure 3.25](#)) and Bureau of Labor Statistics of the United States (2018b; [Figure 3.26](#)), lower extremities was the most commonly injured body part in non-fatal falls in 2012-2021 (average 36.7% in Taiwan, 46.4% in Australia, 31.1% in the U.S.), followed by injuries to the upper extremities (average 28.7% in Taiwan, 19.4% in Australia, 23.4% in the U.S.).

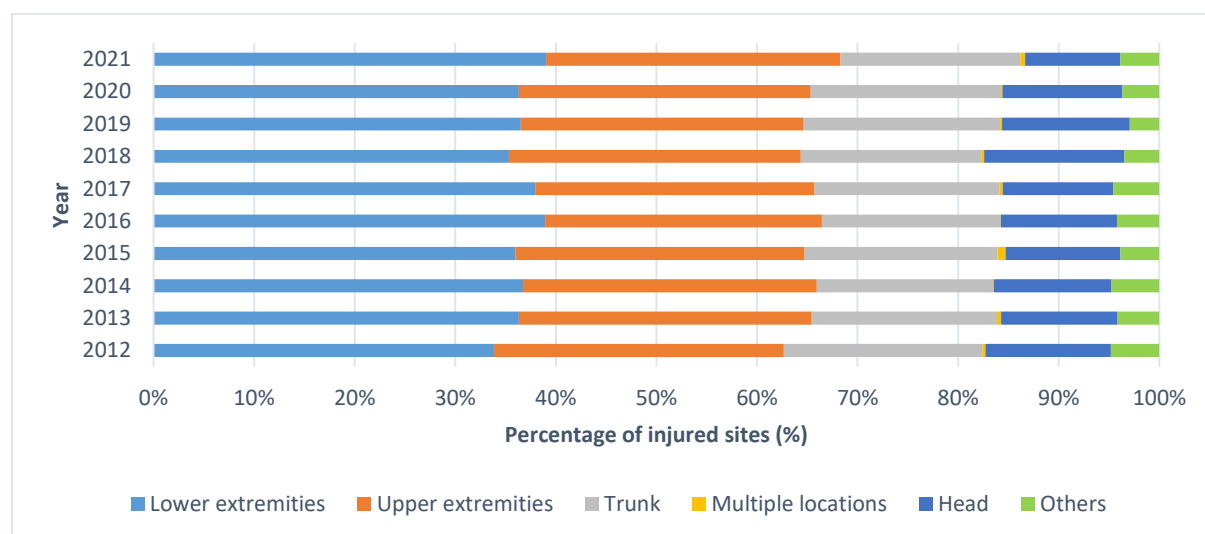


Figure 3.24. Percentage of injured sites caused by non-fatal fall injury in Taiwan, 2012-2021 (Occupational Safety and Health Administration of Taiwan, 2022).

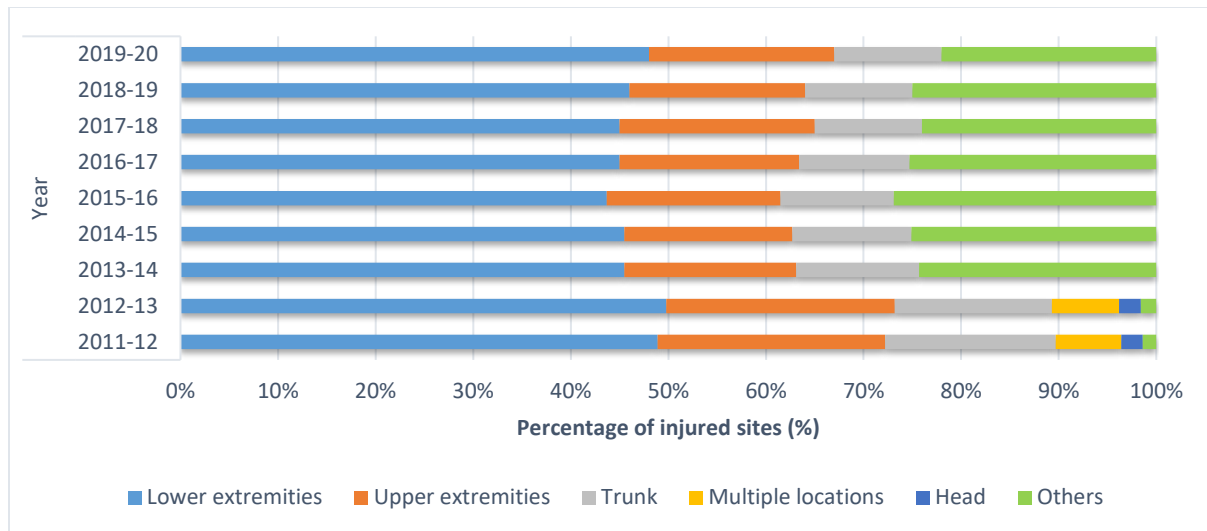


Figure 3.25. Percentage of injured sites caused by non-fatal fall injury in Australia, 2012-2021 (Safe Work Australia 2022a).

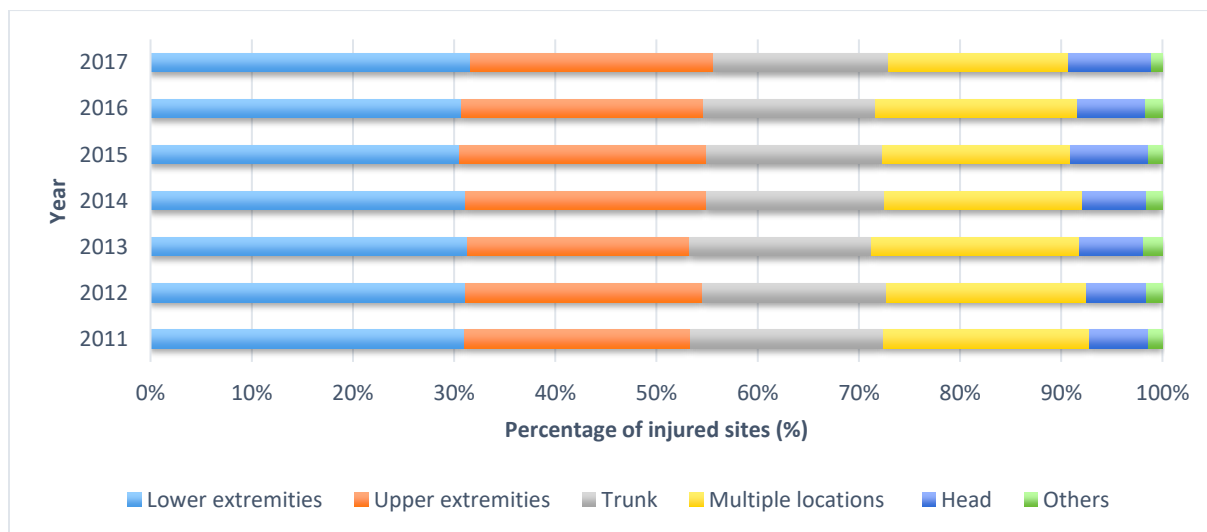


Figure 3.26. Percentage of injured sites caused by non-fatal fall injury in the United States, 2011-2017 (Bureau of Labor Statistics of the U.S. 2018c).

3.4.3 Fatal occupational slip, trip and fall on same level

Fatal occupational slip, trip and fall on same level were extremely rare in Hong Kong in the past decade (average 0.4%). It has the lowest reported percentage of all of its fatal occupational incidents in comparison to other populations such as Australia (average 0.4%), Macau (average 1.5%), Great Britain (1.6%) and Canada (1.5%). The highest reported percentage was found in Singapore (average 9.2%; [Table 4.5](#)).

Table 3.5. Percentage of fatal occupational slip, trip and fall on same level incidents among all fatal incidents in H.K. and other populations from 2012 to 2021.

Populations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Singapore	N/A	4.1%	6.7%	13.6%	9.1%	9.5%	17.1%	7.7%	10.0%	5.4%	9.2%
Japan	3.0%	3.3%	2.0%	3.5%	2.6%	2.2%	3.1%	2.6%	3.5%	3.0%	2.9%
Taiwan	2.4%	2.2%	1.5%	1.9%	1.6%	1.9%	1.8%	2.3%	2.9%	1.2%	2.0%
Great Britain	N/A	N/A	1.4%	0.7%	2.2%	2.8%	1.3%	1.8%	2.1%	0.8%	1.6%
Canada	2.0%	1.7%	1.7%	1.6%	1.4%	1.4%	1.4%	1.2%	1.1%	N/A	1.5%
Macau	N/A	5.3%	0.0%	0.0%	0.0%	0.0%	8.3%	0.0%	0.0%	0.0%	1.5%
Australia¹⁶	1.7%	0.0%	0.5%	0.5%	0.0%	0.5%	0.0%	0.0%	0.5%	N/A	0.4%
Hong Kong	0.0%	0.0%	0.0%	0.0%	0.5%	0.9%	1.4%	0.0%	0.0%	0.8%	0.4%
United States	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note: Data were retrieved from the following sources: Hong Kong 2012-2021: (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b); Japan 2012-2021: (Ministry of Health of Japan, n.d.); Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022); Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.); Great Britain 2014-2021 (Health and Safety Executive of Great Britain, 2022); Macau 2013-2021: (The Labour Affairs Bureau of Macau, 2022); Australia 2012 – 2021: (Safe Work Australia, 2022b)

¹⁶ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

3.5 Occupational fall from height

In the following section, we examined the data related to all occupational fall from height, i.e. including (1) all occupational fall from height (fatal and non-fatal combined), (2) non-fatal occupational fall from height as well as (3) fatal occupational fall from height.

3.5.1 All occupational fall from height (fatal and non-fatal combined)

The incidence rate of all occupational fall from height in Hong Kong was similar to that of Taiwan (*Figure 3.27*). The highest incidence rate was reported in Canada (7.9 per 10,000 workers in 2013) and it was three times higher than that of Hong Kong. Higher incidence rate was also reported in Australia, though Singapore and Taiwan have a significantly lower rate than that of Hong Kong.

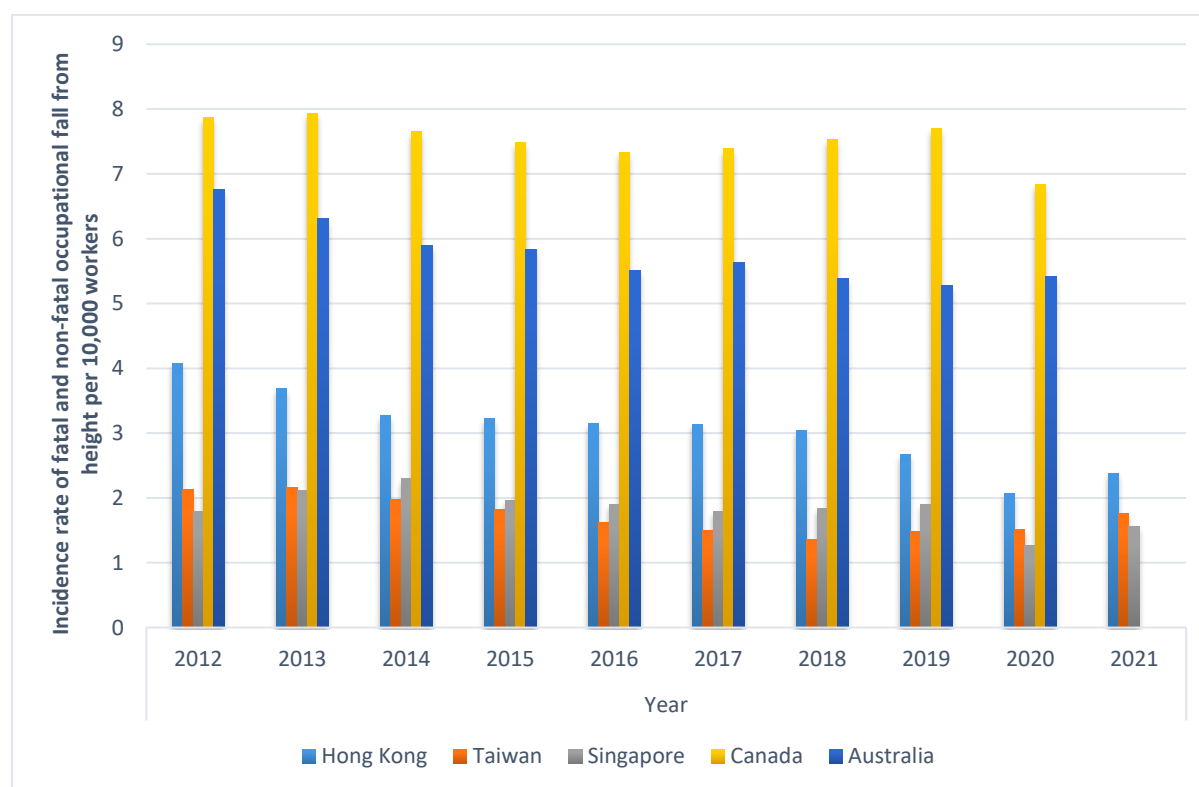


Figure 3.27. Fatal and non-fatal occupational fall from height incidence rate per 10,000 workers in all Industry in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and

Health Administration of Taiwan, 2022), Singapore 2012-2021: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022b), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.; Statistics Canada, n.d.), Australia¹⁷ 2012-2020: (Australian Bureau of Statistics, 2022; Safe Work Australia, 2022a; Safe Work Australia, 2022b)] from 2012 to 2021.

3.5.2 Non-fatal occupational fall from height

Hong Kong has reported the lowest average percentage of non-fatal occupational fall from height among all non-fatal incidents in comparison to data retrieved from other populations ([Table 3.6](#)). With the exception of Japan (averaging 16.6% of all non-fatal incidents over the past 3 years), the percentages of non-fatal occupational fall from height in Asia tended to be lower than those reported in western countries such as Great Britain, Australia, Canada, and the United States.

Table 3.6. Percentage of non-fatal occupational fall from height incidents among all non-fatal incidents in Hong Kong and other populations from 2012 to 2021.

Populations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Japan	17.0 %	17.1 %	17.2 %	17.1 %	17.0 %	16.9 %	16.7 %	17.0 %	16.0 %	14.2 %	16.6%
Great Britain	N/A	N/A	7.7%	7.9%	7.5%	7.7%	7.7%	9.3%	8.1%	8.2%	8.0%
Australia ¹⁸	5.9%	6.0%	5.9%	6.3%	6.2%	6.4%	6.0%	5.8%	5.7%	N/A	6.0%
Canada	5.6%	5.8%	5.6%	5.7%	5.4%	5.4%	5.3%	5.4%	4.8%	N/A	5.4%
United States	5.2%	5.1%	5.3%	5.3%	4.9%	4.8%	N/A	N/A	N/A	N/A	5.1%
Singapore	N/A	5.6%	5.7%	5.4%	5.0%	5.0%	5.0%	4.9%	3.9%	4.1%	4.9%
Taiwan	4.9%	5.2%	4.8%	4.8%	4.9%	4.8%	4.6%	5.0%	5.0%	5.1%	4.9%
Macau	N/A	2.7%	4.4%	3.8%	4.0%	3.4%	3.6%	3.7%	4.6%	5.2%	3.9%
Hong Kong	3.6%	3.5%	3.2%	3.4%	3.2%	3.3%	3.2%	3.0%	2.7%	2.8%	3.2%

Note: Data were retrieved from the following sources: Hong Kong 2012-2021: (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b); Japan 2012-2021: (Ministry of Health of Japan, n.d.), the Great Britain 2014-2021: (Health and Safety Executive of the Great Britain, 2022), Australia 2012-2020: (Safe Work Australia, 2022a), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.), the United States¹⁹ 2012-2017: (Bureau of Labor Statistics of the U.S., 2018b), Singapore 2012-2021: (Ministry of Manpower

¹⁷ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

¹⁸ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

¹⁹ STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018b).

of Singapore, 2022), Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Macau 2013-2021: (The Labour Affairs Bureau of Macau, 2022)

The incidence rate of non-fatal occupational fall from height was higher in Hong Kong in comparison to numbers reported by Taiwan and Singapore; however, it was a lot lower than those reported by Canada and Australia (*Figure 3.28*). Among all populations studied in this report, the incidence rate of non-fatal occupational fall from height of Canada remained on top, as almost all of their occupational fall from height incidents were non-fatal. In contrast, since mortality rate of fall from height incidents in Taiwan was high, once the fatal cases were removed from the analysis, Taiwan has a significantly lower non-fatal fall from height incidence rate than Hong Kong.

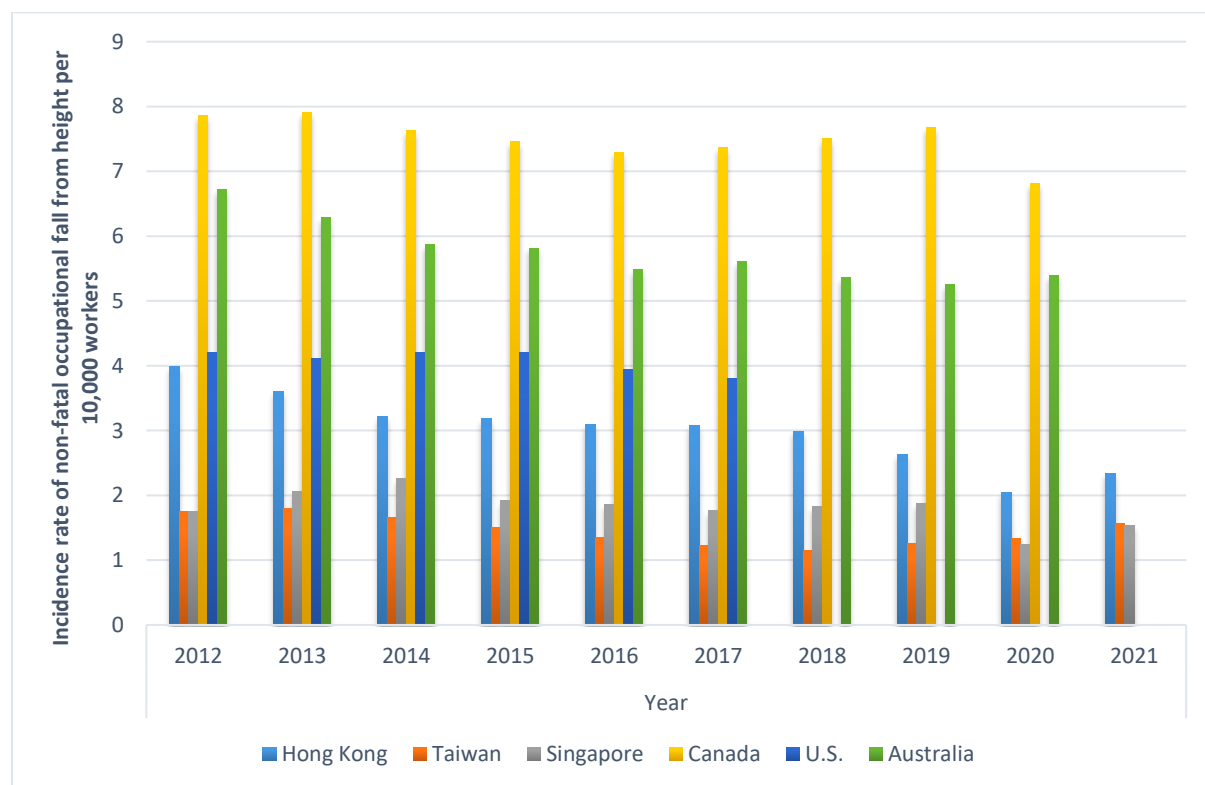


Figure 3.28. Non-fatal occupational fall from height incidence rate per 10,000 workers in all industries in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Singapore 2012-2021: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022b), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.);

Statistics Canada, n.d.), the United States²⁰ 2012-2017: (Bureau of Labor Statistics of U.S., 2018b), Australia²¹: (Australian Bureau of Statistics, 2022; Safe Work Australia, 2022a)] from 2012 to 2021.

3.5.2.1 Non-fatal occupational fall from height (by Industry)

Comparing incidence rates of non-fatal occupational fall from height among different industries in Hong Kong, the manufacturing sector (4.6 per 10,000 workers; [Figure 3.29](#)) had a 2.3 times lower rate than the construction sector (10.6 per 10,000 workers; [Figure 3.30](#)) due to their job nature. Similarly, non-fatal incidence rates of fall from height in the construction sector were generally higher than those in the manufacturing sector worldwide (i.e. 4.8 times higher in the United States, and 3.9 times higher in both Japan and Taiwan). The average non-fatal incidence rate of occupational fall from height in Hong Kong (4.6 per every 10,000 workers) was the highest among the four populations followed by the United States (3.8 per every 10,000 workers) in the manufacturing sector. The rate of Hong Kong was 3.5 times higher than that of Taiwan (1.3 per every 10,000 workers), and 1.6 times higher than the rate of Japan (2.8 per every 10,000 workers; [Figure 3.29](#)).

²⁰ STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018b).

²¹ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

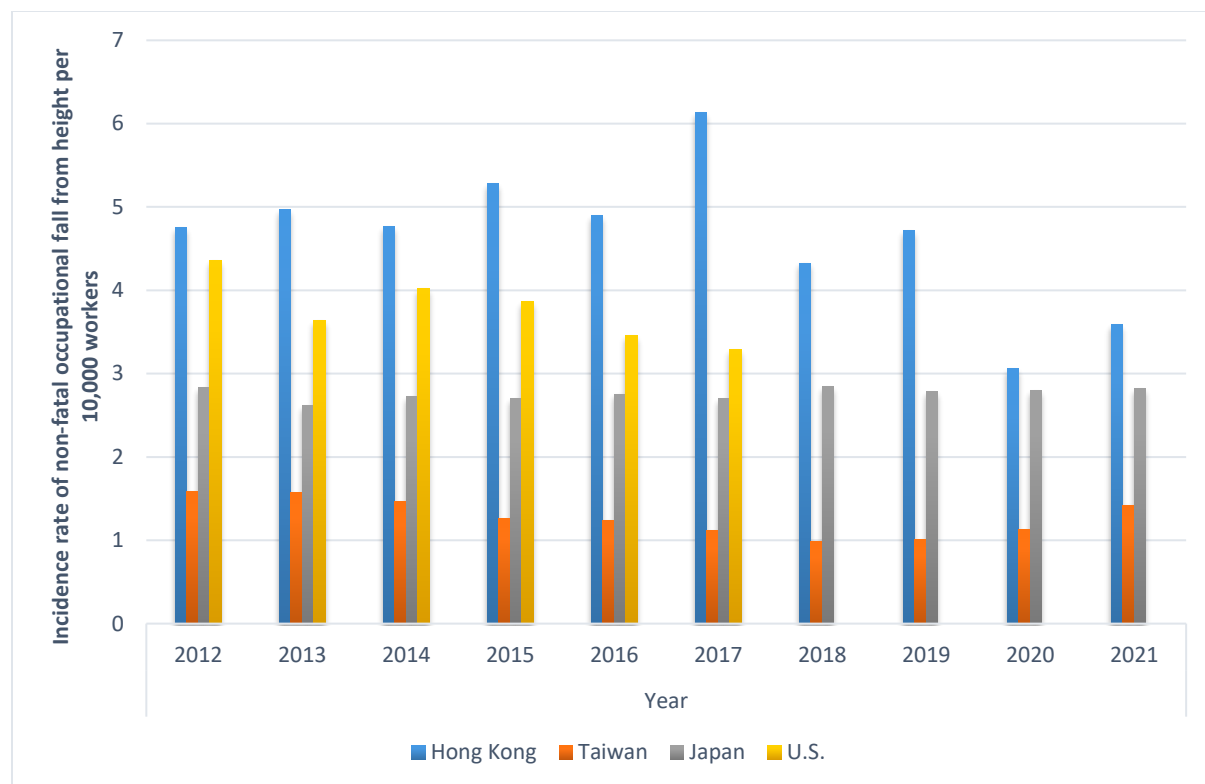


Figure 3.29. Non-fatal occupational fall from height incidence rate per 10,000 workers in the manufacturing sector in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration, 2022), Japan 2012-2021: (Ministry of Health of Japan, n.d.), the United States²² 2012-2017: (Bureau of Labor Statistics of the U.S., 2018b)] from 2012 to 2021.

²² STF on same level including the categories of Fall on Same level and Slip or strip without fall provided by Bureau of Labor Statistics of the U.S. (2018b).

The non-fatal incidence rate of occupational fall from height in Hong Kong (average 10.6 per 10,000 workers) ranked third behind the United States (average 18.2 per 10,000 workers) and Japan (averaging 10.5 per 10,000 workers) in the construction sector ([Figure 3.30](#)). Comparatively, Japan had similar incidence rate as Hong Kong, though Taiwan had the lowest reported incident rate (5.1 per 10,000 workers).

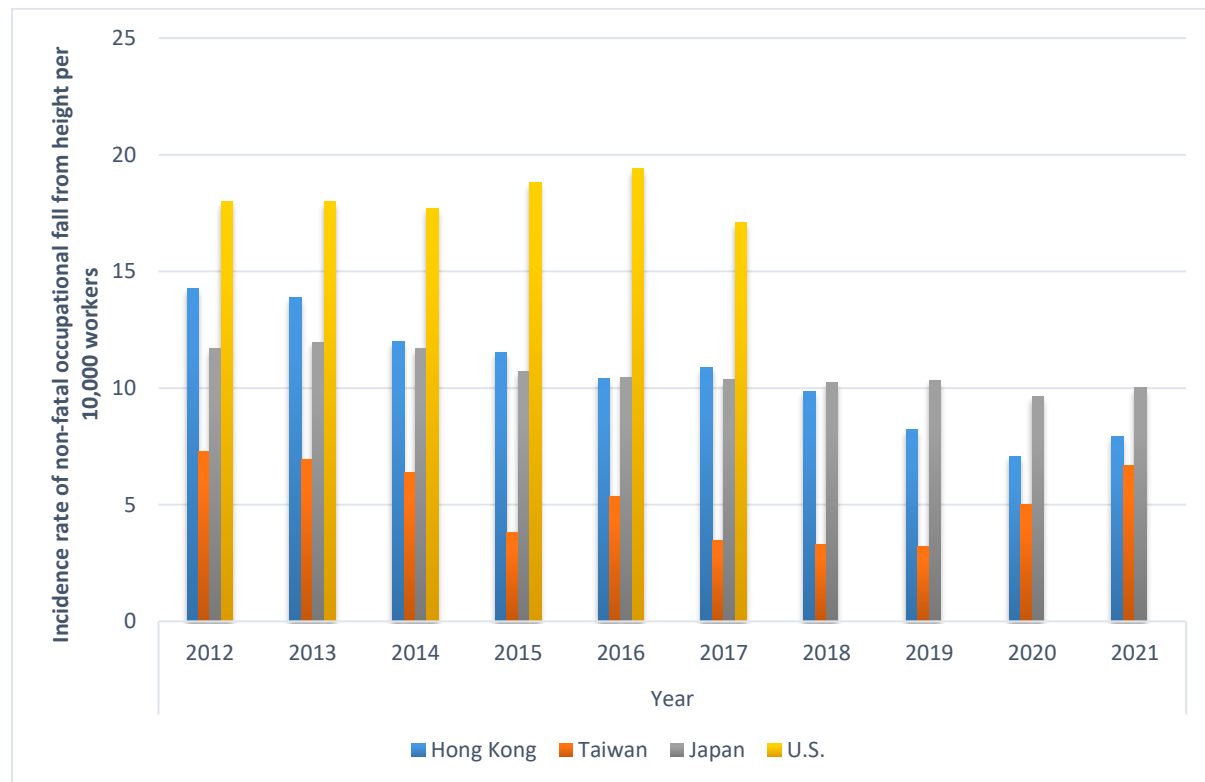


Figure 3.30. Non-fatal occupational fall from height incidence rate per 10,000 workers in the construction sector in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Japan 2012-2021: (Ministry of Health of Japan, n.d.), the United States 2012-2017 (Bureau of Labor Statistics of the U.S., 2018b)] from 2012 to 2021.

3.5.2.2 Non-fatal occupational fall from height (by gender)

Incidence rate of non-fatal occupational fall from height of the two genders has not been reported in Hong Kong; however, according to the Bureau of Labor Statistics of the United States (2018a), the men's incidence rate of non-fatal occupational fall to lower level injuries has been consistently higher than that of the women's (mean difference = 3.8 per 10,000 full-time workers) from 2011 to 2017 (*Figure 3.31*).



Figure 3.31. Non-fatal occupational fall from height incidence rate per 10,000 workers by gender in the United States from 2011 to 2017 (Bureau of Labor Statistics of the U.S., 2018a).

3.5.2.3 Non-fatal occupational fall from height (by age)

In the same way, non-fatal fall from height incident rate in different age group could not be computed for the Hong Kong working population. As reported by the United States (Bureau of Labor Statistics of the U.S., 2018b), the age group of 55 to 64 had the highest incidence rate of non-fatal occupational fall from height injuries (average 6.7 per 10,000 full-time workers), followed by the oldest age group of 65 and over (average 6.3 per 10,000 full-time workers) and the third oldest age group of 45 to 54 (average 6.0 per 10,000 full time workers) in 2011-2017 (*Figure 3.32*).

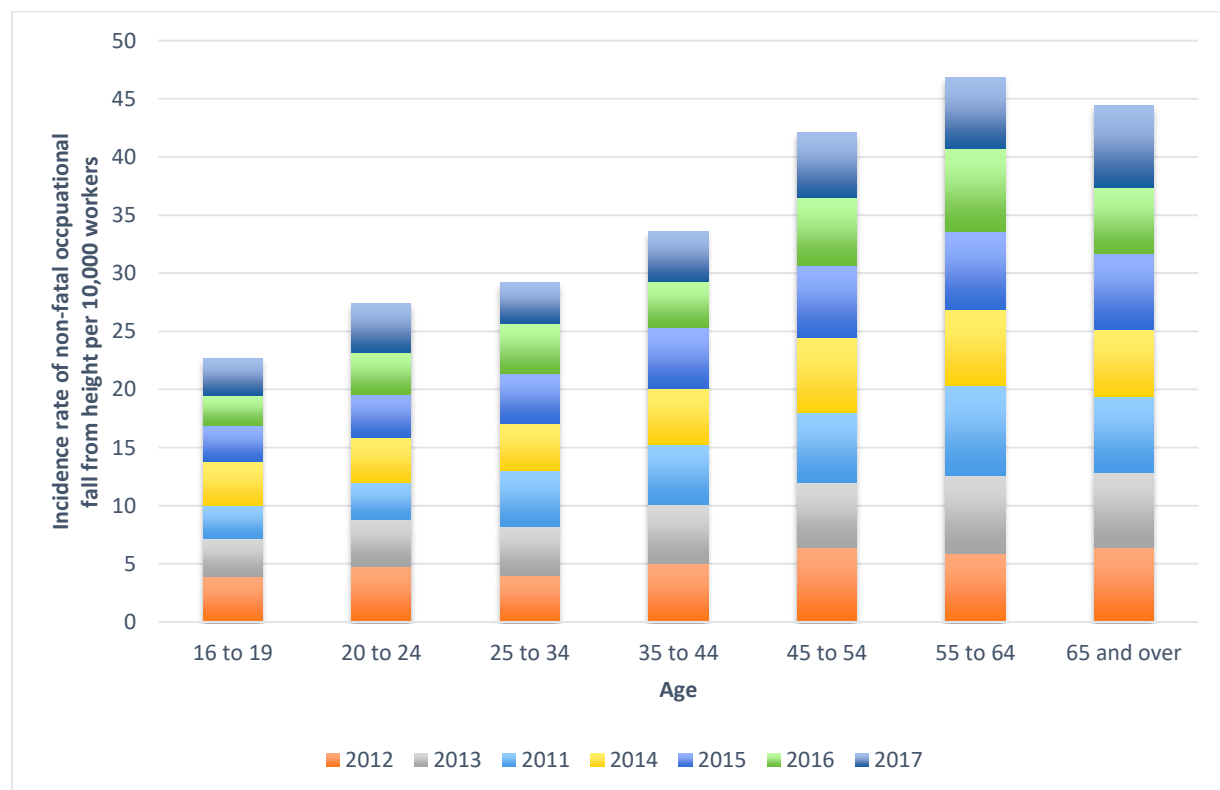


Figure 3.32. Non-fatal occupational fall from height incidence rate per 10,000 workers by age in the United States from 2011 to 2017 (Bureau of Labor Statistics of the U.S., 2018a).

3.5.3 Fatal occupational fall from height

Ranked the second lowest behind Canada, fatal occupational fall from height contributed on average 12.1% of overall fatal incidents in Hong Kong in the past decade, which was lower in comparison to Great Britain (average 27.0%), Japan (average 25.6%), Singapore (average 22.6%), Macau (average 20.7%), Taiwan (average 18.4%), and Australia (average 12.3%). Canada has reported the lowest percentage of fatal occupational fall from height among all fatal incidents in all of the populations investigated (average 5.1%; [Table 3.7](#)).

Table 3.7. Percentage of fatal occupational fall from height incidents among all fatal incidents in H.K. and other populations from 2012 to 2021.

Populations	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
Great Britain	N/A	N/A	29.6 %	25.9 %	24.8 %	28.9 %	28.9 %	27.4 %	24.8 %	23.6 %	26.7%
Japan	24.8 %	25.8 %	24.9 %	25.5 %	25.0 %	26.4 %	28.2 %	25.6 %	23.8 %	25.0 %	25.5%
Singapore	N/A	19.2 %	16.7 %	21.2 %	19.7 %	19.0 %	19.5 %	17.9 %	26.7 %	21.6 %	20.2%
Macau	N/A	0.0%	33.3 %	24.0 %	14.8 %	10.5 %	33.3 %	28.6 %	7.1%	26.7 %	19.8%
Taiwan	19.1 %	20.4 %	18.2 %	19.9 %	18.1 %	23.2 %	17.5 %	20.6 %	15.6 %	16.9 %	18.9%
Australia ²³	13.0 %	12.9 %	11.2 %	13.7 %	13.9 %	15.2 %	11.8 %	11.1 %	11.9 %	N/A	12.7%
Hong Kong	15.8 %	17.6 %	11.0 %	9.0%	8.9%	11.0 %	7.8%	6.8%	5.6%	6.8%	10.0%
Canada	3.8%	5.5%	5.1%	5.2%	5.9%	4.9%	4.9%	6.7%	5.3%	N/A	5.3%

Note: Data were retrieved from the following sources: Hong Kong 2012-2021: (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b); Great Britain 2014-2021 (Health and Safety Executive of Great Britain, 2022); Japan 2012-2021: (Ministry of Health of Japan, n.d.); Singapore 2013-2021: (Ministry of Manpower of Singapore, 2022), Macau 2013-2021: (The Labour Affairs Bureau of Macau, 2022); Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022); Australia 2012 – 2020: (Safe Work Australia, 2022b).Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.)

²³ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

The average fatal incidence rate of occupational fall from height in Hong Kong (5.6 per 1,000,000 workers) was higher than Singapore (3.0 per 1,000,000 workers), Canada (2.7 per 1,000,000 workers), and Australia (2.1 per 1,000,000 workers). However, it was significantly lower than the rate reported by Taiwan (27.2 per 1,000,000 workers), which was the highest among all populations in this study (*Figure 3.33*).

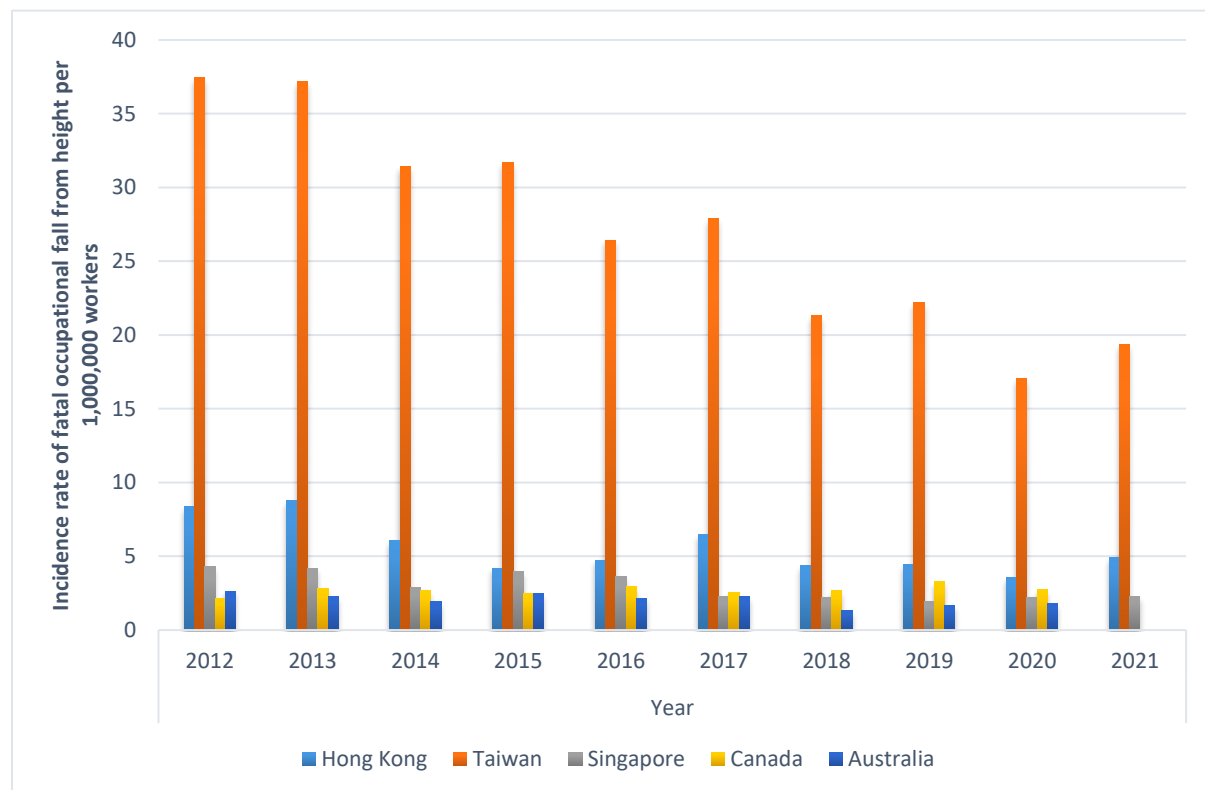


Figure 3.33. Fatal occupational fall from height incidence rate per 1,000,000 workers in all industries in Hong Kong from 2012 to 2021. (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration of Taiwan, 2022), Singapore 2012-2021: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022b), Canada 2012-2020: (Association of Workers' Compensation Boards of Canada, n.d.; Statistics Canada, n.d.), Australia²⁴: (Australian Bureau of Statistics, 2022; Safe Work Australia, 2022a)] from 2012 to 2021..

²⁴ In order to summarize the statistic in an organized way, the data of Australia in 2011-12 was presented as 2012, 2012-13 as 2013, 2013-14 as 2014 and so on.

3.5.3.1 Fatal occupational fall from height (by industry)

Hong Kong (6.4 per 1,000,000 workers) had a lower average incidence rate of fatal occupational fall from height in the manufacturing sector than Taiwan (15.1 per 1,000,000 workers); however, it was higher than those reported in both Singapore (1.5 per 1,000,000 workers) and Japan (2.5 per 1,000,000 workers; *Figure 3.34*).

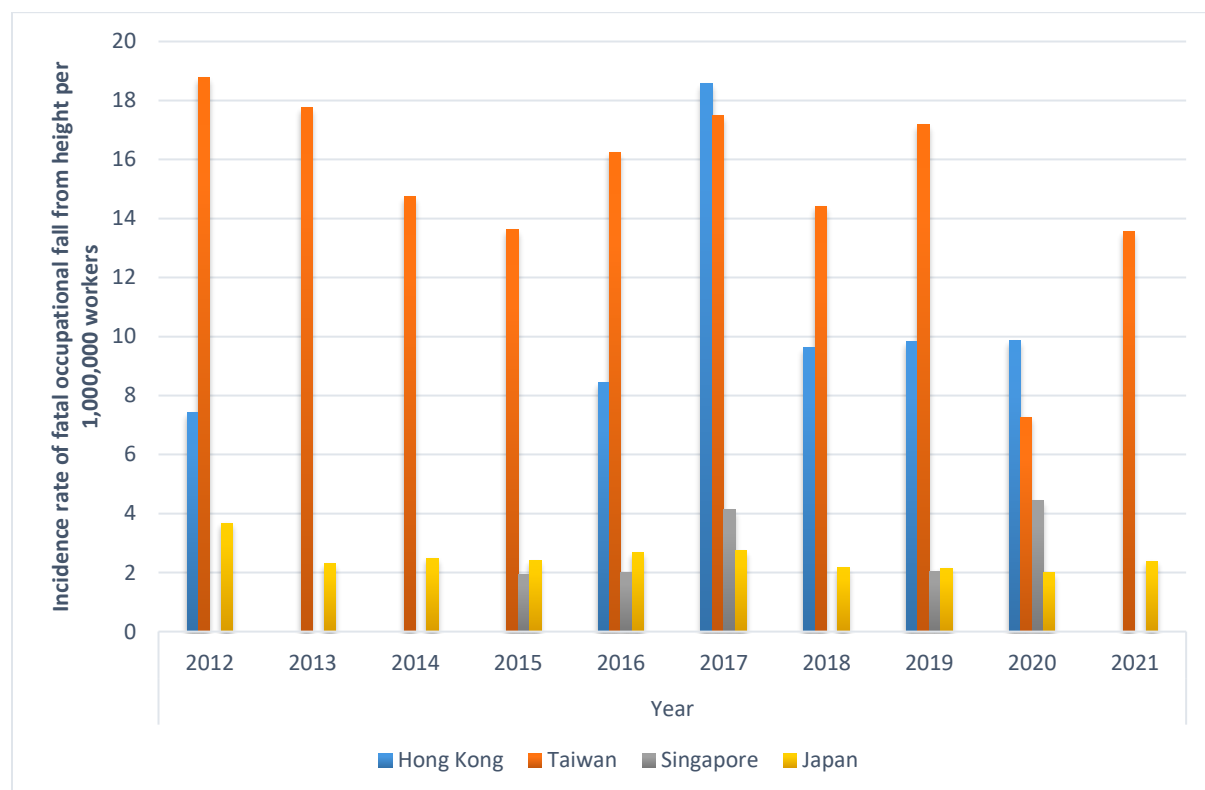


Figure 3.34. Fatal occupational fall from height incidence rate per 1,000,000 workers in the manufacturing sector in Hong Kong (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration, 2022), Singapore 2015-2020: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022c), Japan 2012-2021: (Ministry of Health of Japan, n.d)] from 2012 to 2021.

In Hong Kong, incidence rate of fatal occupational fall from height in the construction sector (31.9 per 1,000,000 workers) was 5.0 times higher than in the manufacturing sector. Hong Kong was ranked second only behind Taiwan, which has a staggeringly high average incidence rate of 466.6 per 1,000,000 workers over the past 10 years. In comparison with Singapore (14.1 per 1,000,000 workers) and Japan (26.3 per 1,000,000 workers), Hong Kong's incidence rate of fatal occupational fall from height in the construction sector appeared to be higher (*Figure 3.35*).

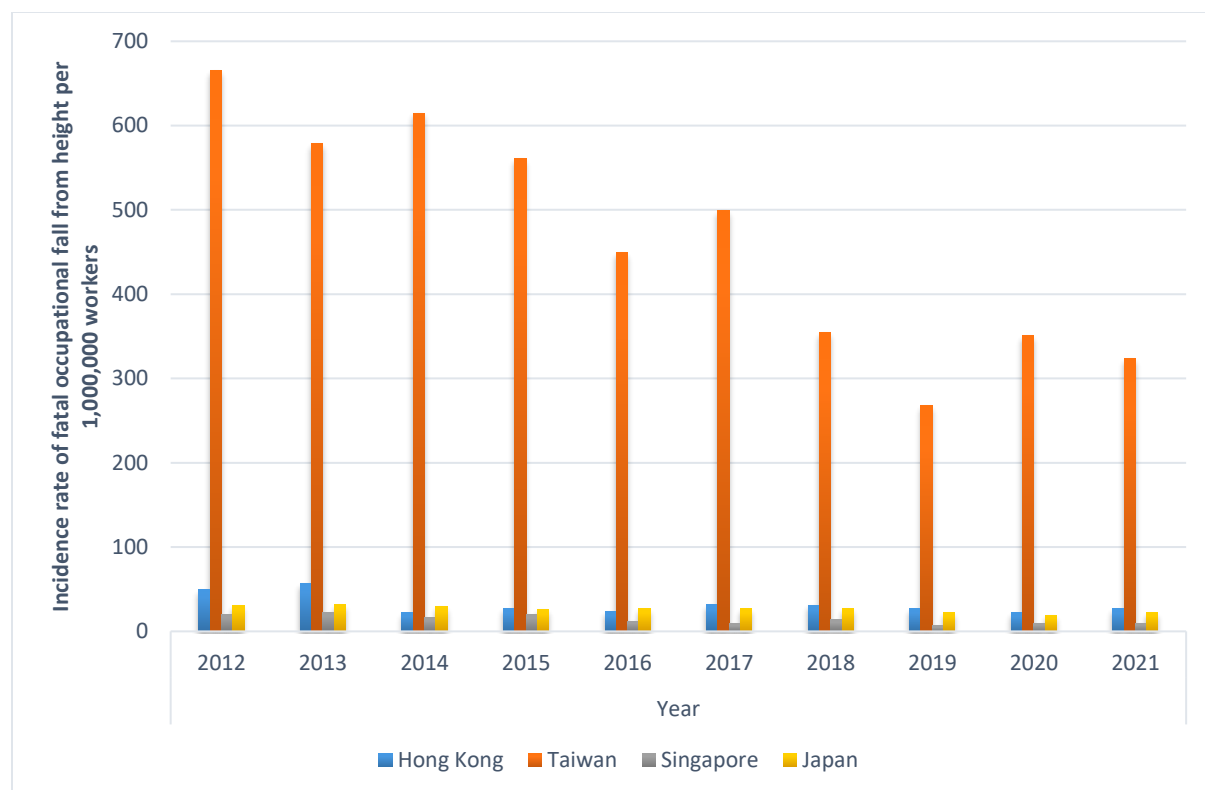


Figure 3.35. Fatal occupational fall from height incidence rate per 1,000,000 workers in the construction sector in H.K. (Labour Department of Hong Kong, 2022a; Labour Department of Hong Kong, 2022b; Census and Statistics Department of Hong Kong, 2022) and other populations [Taiwan 2012-2021: (Occupational Safety and Health Administration, 2022), Singapore 2012-2021: (Ministry of Manpower of Singapore, 2022a; Ministry of Manpower of Singapore, 2022c), Japan 2012-2021: (Ministry of Health of Japan, n.d)] from 2012 to 2021.

4 Literature review : Risk factors of occupational slips, trips and falls on same level

4.1 Introduction

With an increasing prevalence of occupational injuries and even fatalities in slip, trip and fall (STF) in Hong Kong and across the world, it is important to identify common risk factors in order to design the most effective interventions to prevent STF-related casualties effectively. STFs are the result of unintended or unpredictable variation in the contact surface between footwear and underfoot surface. Traditionally, low friction produced by footwear (Gao, Holmér, & Abeysekera, 2008; Grönqvist, 1995) and poor grip of footwear (Gao et al., 2008) were considered as the primary risk factors. In addition, numerous environmental and human factors have been considered as the secondary risk factors leading to STFs (Gao et al., 2008). Nonetheless, the causes of occupational STF injuries are sophisticated that they concern both extrinsic and intrinsic factors (Bentley & Haslam, 2001a), as well as mixed factors (Grönqvist, 1995). Therefore, the risk factors can be deliberated as the outcomes of diversified interactions of environmental, human, work-related, as well as management factors.

Considerable amount of studies has been published to classify the risk factors of STF injuries. These risk factors will be reviewed systematically in this report in the following four sections:

1. Environmental/Extrinsic Factors
2. Human/Intrinsic Factors
3. Work-related Factors
4. Management Factors

However, not all reviewed literatures focused specifically on occupational STFs. Some of them also investigated general fall risk factors outside of workplace; therefore, those findings may be considered as references as they may not reflect the actual situation in occupational settings.

4.2 Risk factors for occupational STF accidents

4.2.1 Environmental/extrinsic factors

Humans are constantly interacting with the surrounding environment. In real-life situations, the unpredictability of the environment creates potential fall hazards that can jeopardize our postural stability. Slip and trip hazards are commonly found everywhere and humans rely on our sensory systems to detect them. Unfortunately, loss of balance still happens from time-to-time due to distraction or the cause of accident is unavoidable (e.g. getting push by an external force). When that happens, we will need to execute fast and ballistic balance recovery reactions to restore our stability. However, it is possible that things we use in occupational settings can interfere with our mobility and/or sensory system, making us more susceptible to falls. The most commonly reported environmental or extrinsic factors are summarized in the following section.

4.2.1.1 Surface condition

One of the most commonly reported environmental hazards causing occupational STF is surface condition. Many studies have examined how surface condition alters the risk of STFs. Uneven or damaged paving and existence of obstacles on the walking surface have been listed as the main environmental factors contributing to STFs (Bentley, 1998; Bentley & Haslam, 2001a; Fothergill, O'Driscoll, & Hashemi, 1995; Gauchard, Chau, Mur, & Perrin, 2001). In Bentley's study on fall risk factors for mail delivery officers in 1998, 86% of the respondents agreed that ill-repaired walking surfaces and road condition were the main contributions to increased fall risk during work, as supported by a review study conducted by Gauchard et al. (2001). Damaged pedestrianized surface was found in more than half of the falls recorded in a survey on falls in public places (Fothergill et al., 1995). In addition, factors including the dimensions of the support surface (Leamon & Murphy, 1995), the smoothness of the surface nature (Leclercq, 1997), and the existence of irregularities of the surface (Fothergill et al., 1995) were also identified as risk factors contributing to STFs. Bentley et al. (2006) went on to investigate STFs among New Zealand construction workers and their findings matched with the other literatures to a large extent. Specifically, it was found that uneven or obstructed underfoot surfaces, as well as inadequate

housekeeping of the work area, were key factors that led to STFs. Observations and interviews carried out to determine the extent of bad housekeeping that adversely influenced the area revealed that the lack of arrangement of surface condition, storehouse, waste removal, etc. are common fall hazards found in workplace. These situations might restrict the passage of workers, and hence, increased the risk of STFs.

Hsiao and Simeonov's review (2001) on falls in roofing workers provided a detailed account of the surface conditions that would attribute to increased fall risks. Firstly, standing or walking on narrow supports and on edges of buildings decreases a person's control of balance and impedes one's emergency reactive ability. Secondly, standing on inclined surfaces increases the risk of slip and fall accidents as the risk of mechanical perturbations would be increased due to greater shear forces at the shoe-floor interface when workers are operating tasks on inclined surfaces (Harper, Warlow, & Clarke, 1967). Thirdly, the surface's frictional properties vary between roofing materials, and couple with the variability of the surface's evenness, firmness, and stability, may cause a worker to provoke emergency reactive control of balance. Similarly, floor covering has also been identified as a factor leading to STFs. The components of permeability (Leclercq, 1997), existence of contaminant on the ground (Bentley et al., 2006) such as wet surfaces, leaves, snow and ice (Bentley, 1998), the form of covering such as liquid, solid and powder, and the surface characteristics such as viscosity and thickness (Leclercq, 1997) could determine the risk of STFs. Gauchard et al. (2001) had emphasized the changes in the properties of floor can cause postural perturbations, and thus, increase the risk of falling.

By collecting responses from postal delivery officers through questionnaires, Bentley and Haslam (2001a) have also found that some form of slippery underfoot conditions as major factors leading to increased risk of falls. Respondents of the study described walking down steep hills, sloped driveways and steps as particularly hazardous in slippery conditions. In addition, more than 50% of the STF accidents reported in the study involved foot slipped initiating incidents. Courtney, Sorock, Manning, Collins, and Holbein-Jenny (2001) had claimed that falls triggered by slips are the most common STFs on the same level. When the required coefficient of friction

to uphold walking at the shoe-floor interface overtook the available coefficient of friction (ACOF), a slip would occur (Hanson, Redfern, & Mazumdar, 1999). However, future studies are needed to establish the required coefficient of friction for accomplishing various tasks under different circumstances, i.e. walking/turning/running on assorted floor surfaces in occupational settings (Chang, Leclercq, Lockhart, & Haslam, 2016).

4.2.1.2 *Weather*

Partially related to outdoor surface condition is weather, as wet surfaces, leaves, snow and ice have already been reported as fall hazards in previous studies (Bentley, 1998). Therefore, adverse weather condition has been reported as one of the key risk factors that lead to STFs for outdoor workers (Bentley & Haslam, 2001a; Bentley et al., 2006). Specifically, Bentley & Haslam (2001a) has reported that the most common underfoot hazards on same level involved in slipping accidents were ice (46%), wet/grass (24%) and snow (17%); hence, it is not surprising that there are more falls in the winter months in the UK. Besides, Bentley et al. (2006) investigated falls among the construction workers in New Zealand and showed that adverse weather such as rain for those who work on same level, and strong wind gusts for those who work outside at an elevation, as key factors that lead to occupational STFs.

4.2.1.3 *Impaired vision*

As visual input plays a significant role in balance control, obstacle avoidance, as well as foot placement and handhold identification, factors that degrade visual acuity can have adverse effects on our postural stability, as well as our ability to restore balance control after a perturbation (Paulus, Straube, & Brandt, 1984).

4.2.1.3.1 Lighting

In a study on mail delivering workers, Bentley and Haslam (2001a) had found that 35% of the respondent had listed absence of or inadequate lighting, such as poor natural lighting conditions in the early winter mornings when postal workers are busiest at the beginning of the day, as a major STFs risk factor. Insufficient lighting was also proved as a key contributing factor to falls in public region (Fothergill et al., 1995). Bentley et al. (2005) reported that 2% of the recorded STFs accidents in the study were caused by insufficient illumination/weather conditions. Under a circumstance with insufficient illumination, workers may not be able to identify the obstacles, uneven pave or unsafe environment while walking and thus increase their risk of STFs.

4.2.1.3.2 Visual field

Having unobstructed visual field is essential for gait modulation; therefore, impaired vision can cause gait disturbance and loss of balance (Chang et al., 2016). Bentley et al. (2005) showed that impaired visual cues were associated with higher risk of STFs. Concurrent visual task (45%) and carrying something that obscured view of underfoot hazard (13%) were the main causes that lead to workers not being able to detect underfoot hazards. Joh, Adolph, Campbell, and Eppler (2006) also claimed that good visual cues are essential in preventing slip-related injuries over low-fiction surfaces as occupational slips are common and can cause serious consequences. Individuals tend to use shine or light reflection as an indicator to judge the slipperiness of ground surface (Joh et al., 2006; Lesch, Chang, & Chang, 2008), and subsequently choose less slippery walking route based on shine (Joh et al., 2006). According to Lesch et al. (2008), there is a significant correlation between slipperiness, reflectiveness, texture, traction, light/dark with coefficient of friction. Specifically, reflectiveness rating has the strongest correlation with perceived slipperiness, while texture ratings has the strongest correlation with coefficient of friction. Anticipating surface conditions can help walkers modulate their gait, as well as lower their risk of slipping. However, it is not completely reliable to judge the slipperiness of floor by shine alone because the color of the testing surface, viewing distance and lighting conditions are other important factors that affect both shine and slip rating but not the actual coefficient of friction (Joh et al., 2006).

The useful field of view (UFOV) is the visual area in which useful information can be extracted by oneself from a brief glance or fixation (Ball, Beard, Roenker, Miller, & Griggs, 1988). According to Reed-Jones, Reed-Jones, and Hollands (2014), UFOV performance is at the lowest in stepping or walking conditions compared to in seated and standing conditions, since the person has to process more complicated visual flow as the individual is moving. Although no significant difference was found between standing and seated UFOV performance, UFOV divided-attention performance can be significantly influenced by postural demand. Reduced performance of UFOV has been shown as a predictor of increasing risk of fall (Vance et al., 2006).

4.2.1.4 Equipment

Personal protective equipment, including footwear and eyewear, may adversely cause sensory interface of an individual with the surrounding environment. Furthermore, some protective equipment may interfere with natural movement, which in turn can influence balance controlling ability of workers (Hsiao & Simeonov, 2001). For example, Punakallio, Lusa, and Luukkonen (2003) had shown that postural and functional balance was diminished significantly while the firefighters are wearing their fire protective equipment. Other than thick protective equipment, footwear and eyewear are commonly identified as equipment that can increase the risk of falling in occupational settings.

4.2.1.4.1 Footwear

When humans are walking and meanwhile retaining dynamic stability, feet are usually the sole body parts that make direct contact to the ground and external environment (Chiou, Bhattacharya, & Succop, 1996). Footwear exists as a sensory interface between the feet and the surface of support (Hsiao & Simeonov, 2001); therefore, footwear has a key biomechanical role in slip and fall incidents because it can alter the gait gesture and dynamic stability (Chiou et al., 1996). Besides the ground surface condition and properties, slip resistance of shoes can be affected by many different variables, ranging from the significance of the nature, shape, stiffness, and relief

of the sole, as well as the wear status approaching to the floor (Chiou et al., 1996; Fothergill et al., 1995; Tisserand, 1985; Wilson & Perkins, 1985).

Shoe sole markedly influences the frictional properties of the footwear (Grönqvist, 1995). In addition, the ability of perceiving the real slipperiness of a surface can also be altered (Chiou et al., 1996). The characteristics of the shoe sole can disrupt the usual balance controlling ability and downgrade postural stability if not properly designed. It has been illustrated that foot position awareness would be lowered by shoes with thick and soft soles, thus increasing the risk of STFs. On the other hand, shoes with thin and hard soles contribute to better walking stability (Robbins, Waked, Allard, McClaran, & Krouglicof, 1997; Robbins, Waked, Gouw, & McClaran, 1994; Waked, Robbins, & McClaran, 1997). Moreover, tread depth, width, as well as orientation of tread have been proved to significantly influence the available coefficient of friction (ACOF) measured by a portable slip meter (Li & Chen, 2005; Li, Wu, & Lin, 2006). The same studies also showed that a greater ACOF can be generated by footwear pads with grooves perpendicular to the friction direction rather than in parallel under wet circumstances.

4.2.1.4.2 Eyewear

Though spectacles are essential for many individuals to improve their visual acuity to prevent falls, other eyewear can act as a sensory interface to the visual system. It has been reported that bifocal lens could lead to errors in depth perception, especially while walking down the stairs or slopes (Black, Maki, & Fernie, 1993). Furthermore, protective eyewear or alternative equipment providing head or face protection may limit the visual field, and hence would reduce postural stability (Hsiao & Simeonov, 2001). Besides interfering with visual input, postural stability can be further compromised because the additional head weight can affect natural head and neck movements. Such adverse effects are most prominent among individuals who are operating sensory-challenging tasks such as navigating ladders, scaffolding and elevated surfaces, which are similar to the job duties of a construction worker (Wade, Weimar, & Davis, 2004).

Wearing facemask or eye-mask as a part of the protective equipment is common for some occupations; for example, firefighters wear facemask as part of the self-contained breathing apparatus (Kong, Suyama, & Hostler, 2013) and construction workers wear eye mask when there is a risk of eye injury, e.g. when breaking concrete. Even though protective eyewear could lower the risk of eye injury, sensory input from the visual system will be deteriorated due to reduction of visual clarity and field of view (Wade et al., 2004). Therefore, balance control would be weakened because of the impaired sensory input from the visual system (Kong et al., 2013). For the same reasons, Seliga et al. (1991) also reported that wearing a full-face respirator would impair the performance of postural sway under the circumstance of larger workload. Though wearing thermal protective clothing and self-contained breathing apparatus can both significantly affect functional balance control, Punakallio et al. (2003) have found that functional balance can be further weakened when firefighters are wearing protective facemask. Besides adversely affecting the workers' abilities to maintain postural stability, it was found that these protective equipment could also alter their abilities to regain postural control when they were being perturbed (Wade et al., 2004), which explained the increased fall risk associated with protective eyewear and facemask.

4.2.2 Human/intrinsic factors

Besides environmental and extrinsic factors, some individual intrinsic attributes are also strong predictors of occupational STF. Having good balance control, generally described as postural stability or static/dynamic balance, is critical in preventing STF in workplace. In order to facilitate a person to keep an upstanding posture, the ability of maintaining or returning the center of mass (COM) over the base of support (BOS) is the key in preventing falls (Horak, 1987). Weight shifting or weight transfer happens all the time during static or dynamic situations. For example, body weight of an individual is relocated from the rearfoot to the forefoot upon the heel touches the floor when a human is walking. Relevant regulation of step placement can help to sustain dynamic balance by controlling the COM position relative to the BOS (Kuo & Donelan, 2010; Verrel, Lövdén, & Lindenberger, 2010). In general, individuals with poor balance control will fall more easily (Punakallio, Hirvonen, & Grönqvist, 2005). Kong et al. (2013) showed that

greater slip distance, which can potentially lead to a fall, was associated with the firefighters who performed badly in dynamic balance test, regardless of age.

According to Manchester, Woollacott, Zederbauer-Hylton, and Marin (1989), sensory inputs, including visual, somatosensory and vestibular system, contribute to balance control by integrating the multi-sensory input in the central nervous system. It is well known that vestibular dysfunction can lead to sudden fall in adults (Brandt & Dieterich, 1993). Similarly, postural ability would be adversely affected by disruption in any sensory inputs. Besides sensory inputs, balance control could be affected by many other factors, such as ageing, functional fitness, muscle strength, fatigue, load carrying, surface condition, etc. In the following sections, we will review some of the most common intrinsic risk factors.

4.2.2.1 Age

Many of the studies on occupational falls have commonly identified age as a significant risk factor for falling in workplace (Agnew & Suruda, 1993; Buck & Coleman, 1985; Chang et al., 2016; Kemmlert & Lundholm, 1998; Laflamme & Menckel, 1995; Lord & Clark, 1996; Punakallio et al., 2005; Yeoh, Lockhart, & Wu, 2013; Zhang, Lockhart, & Soangra, 2014). Buck and Coleman (1985) studied workers aged 16 to 60 and found that older workers were more likely to experience STF on same level. Moreover, Laflamme and Menckel (1995) revealed that older workers, especially women, were at higher risk in STF accidents than the youngsters. Similarly, Kemmlert and Lundholm (1998) had shown that the rate of recorded STF accidents was highest in the group of aged 45 years or more. Besides falling more frequently, the consequences of falls tended to be more severe for the older workers since higher risk of fatal fall has been reported for those who are 45 or over (Agnew & Suruda, 1993). An interesting finding was shown in Yeoh et al.'s study (2013). Besides finding that the frequency of STF was associated with age, the group consisted of the youngest employee aged 16 to 19 had higher fall prevalence compared to the group aged 20 to 44 (Yeoh et al., 2013), possibly due to their inexperience and risk-taking mentality.

Chang et al. (2016) emphasized age as an important predictor for STFs because older workers tended to have instable gait, degraded sensory sensitivity, as well as declined rapid torque development capacity. According to the study of Punakallio et al. (2005), older firefighters tended to have longer slip distances in comparison to the younger firefighters, especially when walking at higher speed. Also, younger firefighters performed better in postural balance with eyes closed than the older subjects (Punakallio et al., 2003), suggesting that older firefighters relied more on their visual input for balance than their younger colleagues. As reported by a large cohort study on Canadian firefighters, firefighters aged 40-44 fell and slipped more frequently while moving (including walking, running, climbing and descending stairs or ladder) than the younger firefighters among 1,041 accident reports (Cloutier & Champoux, 2000).

Furthermore, suffering from age-related balance problem is inevitable along with the aging process. Many age-related changes can affect older employees' balance and lead to their increased risk of STF; e.g. diminished visual performance (Sekuler, Bennett, & Mamelak, 2000), declined muscle strength (Lockhart, Smith, & Woldstad, 2005), and reduced balance control capacity (Punakallio, 2003). Stability would be adversely affected by age-related changes, such as, visual acuity, adaptation to dark, peripheral vision, contrast sensitivity, and accommodation ability (Tinetti & Speechley, 1989). Reductions in the useful field of view (UFOV) have long been known to occur with aging (Sekuler et al., 2000). Reduced UFOV performance, particularly divided-attention sub-tests, correlates well with increased vehicular crash risk, obstacle collisions, and propensity for falls. Likewise, isometric muscle strength generally climaxes in the middle of twenties and then declines gently until the age of fifty, followed by accelerated downturns thereafter (Astrand & Rodahl, 1986). As a result, reactive balance control from slip perturbations could be undermined by age-related changes as high muscle power is needed to produce fast ballistic stepping and grasping movements to prevent falls (Lockhart et al., 2005). Moreover, the risk of fall would be increasingly associated with aging because of declined function of the vestibular system and proprioception, reduced sensitivity of cutaneous, delayed nerve conduction and information processing, lower strength and slower contraction time of muscles, and reduced range of motion with increased joint stiffness (Black et al., 1993; Tinetti & Speechley, 1989). In addition, deterioration of balance abilities with aging among physical demanding jobs has also

been shown (Punakallio, 2003). Zhang et al. (2014) suggested that fatigue could provoke the risk of fall in a group of older employee due to their decreased endurance and fitness condition.

On the other hand, some studies have questioned the relationship between age and occupational STF as inconsistent results have also been published previously. Lockhart, Smith, Woldstad, and Li (2000) studied 42 subjects from three age groups utilizing biomechanical parameters, muscle strength and sensory measurement. In their lab-based study, there was no significant age effect on slip frequency among their participants (possibly the elderly being tested were relatively fit), though the recovery processes of younger individuals were much faster and effective. Furthermore, among specific occupational settings, age was not associated with the risk of workplace STF. For examples, no significant association between age and the incidence of STF accidents was found among mail delivery officers in the UK (Bentley, 1998), as well as firefighters in the US and Poland (Kong et al., 2013). It has been reported that age was not a significant risk factor on three types of traumatic injuries at the scene of a fire, including falls, as reported in a case-control study of approximately 1,200 firefighters in the United States (Helneman, Shy, & Checkoway, 1989). Similarly, the study of Szubert and Sobala (2002) showed that the frequency of on-duty injuries was not significantly aged-dependent among 1,503 Polish firefighters, though time loss due to injuries raised by 20% with increasing age of the subjects, as older firefighters took longer to recover from their injuries.

In other sectors, the studies of Leclercq and Thouy (2004) and Leclercq, Thouy, and Rossignol (2007) investigated occupational falls in offices and found that older workers actually encountered less occupational STF than the younger colleagues in three of four companies. Additionally, Courtney et al. (2013) discovered that the incidence rate of slipping decreased with increasing age in fast food restaurants. It was possible that in some sectors, the more senior staffs would take on different roles to minimize their exposure to fall hazards. It was also possible that in some sectors such as firefighting, constant physical training has kept the older staffs in similar physical fitness condition as the younger counterparts, suggesting the importance of fitness maintenance among the older employees.

4.2.2.2 Gender

Similar to age, gender has been listed as a risk factor for occupational STF as several studies have shown that women are more susceptible to occupational STF than men. By examining the data of the United States Bureau of Labor Statistics 2010, Yeoh et al. (2013) have shown that 21.7 per every ten thousand female workers took one or more days away from work because of same level falls, which outnumbered the incidence of male workers by close to two-folds (12.1 per every ten thousands). Similarly, Bentley (1998) noticed that the incidence rate of STF among female mail delivery workers was 12.8 per every ten thousand workers, which was around 50% more than the male workers (8.2 per every ten thousand workers). In addition, older workers, especially female workers, were more likely to experience STF (Laflamme & Menckel, 1995). Both older men and women reported STF accidents more frequently than younger people of the same gender (Kemmlert & Lundholm, 1998); however, the number of STF accidents occurred among older women was twice as much as their younger colleagues (Kemmlert & Lundholm, 1998). Most of the recorded women STF accidents happened while the tasks were ongoing, or the employees were moving between tasks. Around 87% of the accidents recorded came from three main categories: (1) slips on floor or missing of steps, (2) snow and ice, and (3) material, oil, grease, or water on the floor. Nenonen (2013) also analyzed the data of European accidents and found that the ratio of female worker encountering slipping, stumbling or falling was larger than any of the other types of occupational accidents.

Nonetheless, the gender difference remained unclear for some occupational sectors. Courtney and colleagues (2013) discovered no gender difference in fall rate in a prospective study on slipping in fast food restaurant settings. Chang et al. (2016) elaborated that the general positions or roles that took place by the two genders might be different in various workplaces; thus, might correspondingly influence the type and amount of fall hazards that they were exposed to. On the other hand, female workers may have to use higher percentage of their ability or strength for some physical-demanding tasks compared to males. For example, bringing excessive amount of mail parcel is one of the common tasks in postal delivery and it may be a burden to female workers and

further affect their balance recovery abilities during a STF initiating incident (Bentley, 1998). Therefore, these two reasons can possibly explain the gender variation in the occurrence of STF on same level, as for the age-factor.

4.2.2.3 Functional fitness and muscle strength

Muscle strength is one of the components that determines a person's ability to maintain balance. Low muscle strength is often associated with declined balance control, which is a fundamental risk factor for falls (Tinetti & Speechley, 1989). According to Islam et al. (2004), muscle strength, cardiorespiratory endurance, and flexibility are some physical fitness components that contribute to functional fitness. Moreover, functional fitness determines the ability of a person accomplishing his/her daily physical tasks. As all human movements rely on the contraction of skeletal muscles, muscle strength is an essential factor contributing to balance control (Islam et al., 2004). For example, firefighters with aerobic and resistance training achieve better result in functional balance test than the group without physical training (Kong, Suyama, Cham, & Hostler, 2012).

Weaker lower extremities muscle strength and functional fitness would lead to increased risk of fall (Cham & Redfern, 2001; Kulas, Zalewski, Hortobagyi, & DeVita, 2008; Lockhart et al., 2000; Pijnappels, Bobbert, & van Dieën, 2005; Tang, Woollacott, & Chong, 1998). Specifically, Pijnappels et al. (2005) found that lower limb strength is a crucial factor in trips recovery; therefore, training aimed at muscle strength should lower the risk of fall. Similarly, Kulas et al. (2008) showed that the position of the trunk could influence muscle strength of the legs, especially the hamstrings, which are important for stabilizing the trunk as well as for balance recovery. The strength of leg and thigh muscles, as well as the coordination of lower limbs movement, have been proved as crucial factors in controlling reactive balance control in slips during the stage of heel strike (Tang et al., 1998). Additionally, the knee flexor and hip flexor muscles were also found to be taking up important responsibilities in corrective balance reactions (Cham & Redfern, 2001). Specifically, among the numerous age-related physiological changes, it was found that muscle strength, such as quadriceps strength (Black et al., 1993; Lord & Clark, 1996; Lord, Ward,

Williams, & Anstey, 1994; Tinetti & Speechley, 1989) and grip dynamometry (Stalenhoef, Diederiks, Knottnerus, Kester, & Crebolder, 2002), played an important role in fall prevention. In addition, a small but significant correlation was found among trunk muscle strength with functional balance performance and falls in older adults (Granacher, Gollhofer, Hortobágyi, Kressig, & Muehlbauer, 2013). Contrary, Punakallio et al. (2005) examined muscular strength as well as endurance among male firefighters and found no clear relationship with the risk of falls and slips in this special population. Possibly, relatively small sample size and the assessment method of muscular capacity were the limiting factors to the generalizability of their findings.

It is known that rapid balance-recovery reactions (i.e. grasping an external object or taking a step) are commonly executed and functionally important responses in fall prevention. In responding to a slip, reactive recovery often consists of a very quick onset of flexor synergy, a great arm elevation action and an adjusted swing limbs trajectory (Marigold & Patla, 2002). Moreover, Redfern et al. (2001) have shown that arm swing and compensatory grasping/stepping are capable for restoring postural balance. However, a number of age-related deteriorations in the neural, sensory, and/or musculoskeletal systems can severely impact the speed, accuracy, and effectiveness of these reactions (Maki & McIlroy, 1997, 1999, 2003). As a result, degraded performance of both the upper and lower extremities has also been shown to be an important risk factor of STF.

Given that falls tend to happen very quickly, having high muscle strength alone is not sufficient in preventing falls (Morris et al., 2007). Having high muscle power is therefore essential for the execution of the fast ballistic arm and leg movements in balance recovery reactions. Studies have shown that faster reaction time (Black et al., 1993; Lord & Clark, 1996; Tinetti & Speechley, 1989; van den Bogert, Pavol, & Grabiner, 2002) and faster rate of muscle tension development (Pijnappels et al., 2005) are essential to avoid falls. But why do some people react faster than others? First of all, it is very important to have good tactile sensitivity (Lord & Clark, 1996) and feet quality (Stalenhoef et al., 2002) to sense the shift of one's Center of Mass over the Base of Support to have an early detection of postural disturbance. Next, an individual has to have high

nerve conduction speed (Black et al., 1993; Tinetti & Speechley, 1989) to send the afferent signal to the Central Nervous System and efferent signal to the muscles quickly to prevent falls from happening. However, individuals with stiffed joint and lower range of motion are at higher risk of fall (Black et al., 1993; Tinetti & Speechley, 1989) as they often suffer from impaired gait and balance control (Lord & Clark, 1996).

4.2.2.4 *Body Mass Index (BMI)*

Chau et al. (2004) found that the construction workers who are overweight and obese (i.e. BMI equals to or exceeds 26) are more likely to experience falls than the normal weight coworkers. Likewise, Koepp, Snedden, and Levine (2015) showed that obesity was associated with STF injuries in the workplace of applied engineering. The risk of slip-induced fall was greater among young obese grownups in gait assessment because of wider step width (Wu, Lockhart, & Yeoh, 2012). Michaelides, Parpa, Henry, Thompson, and Brown (2011) also revealed that bad performance on physical ability test was associated with higher body mass index and body fat among firefighters. Unlike in occupational settings, a lab-based study has shown that there was no difference in their ability to recover from externally applied perturbations for obese and normal-weight individuals (Miller, Matrangola, & Madigan, 2011). Possibly, those who are overweight or obese experience fatigue more often, and fatigue has been shown in many studies as an important factor leading to falls (Goh & Love, 2010).

4.2.2.5 *Fatigue*

Fatigue has been shown to impair balance control by a large body of research (Johnston, Howard, Cawley, & Losse, 1998; Lepers, Bigard, Diard, Gouteyron, & Guezennec, 1997; Lundin, Feuerbach, & Grabiner, 1993; Nardone, Tarantola, Giordano, & Schieppati, 1997; Pendergrass, Moore, & Gerber, 2003; Seliga et al., 1991), as it can lead to poorer motor control performances (Johnston et al., 1998), loss of postural stability (Nardone et al., 1997) and increased risk of slips (Zhang et al., 2014). Muscle fatigue can lead to increased postural sway and decreased balance ability after running as little as 2-miles (Pendergrass et al., 2003) and as much as 15.5-miles

(Lepers et al., 1997). Moreover, Seliga et al. (1991) showed that various levels of work-load (light, moderate or heavy) prompted proprioceptive fatigue effect on the nervous system, leading to poorer performance on their postural balance sway test. Such effect is exacerbated by the effect of age-related differences on muscle strength (Lockhart et al., 2005), as older workers have higher risk of falls than their younger counterparts (Zhang et al., 2014).

Fatigue of localized muscle has been illustrated as a possible risk factor causing slip-induced falls (Parijat & Lockhart, 2008). Studies have shown that fatigue of the lower limb muscles can affect various kinematic and kinetic gait variables, leading to disrupted gait performance (Helbostad, Leirfall, Moe-Nilssen, & Sletvold, 2007; Zhang et al., 2014), impaired locomotor control (Johnston et al., 1998), heightened risk of slip-induced falls (Helbostad et al., 2007; Lockhart, Woldstad, & Smith, 2003; Parijat & Lockhart, 2008), as well as increased risk of injurious falls (Zhang et al., 2014). Furthermore, a delayed response was initiated during balance recovery from a postural disturbance due to fatigue of knee extensor muscle (Parijat & Lockhart, 2008). Possibly, the delay in balance recovery reactions was at least partially related to the proprioceptive responses to mild and maximum fatigue (Gear, 2011).

Nevertheless, there were some contradictory findings in the literature. Egan et al. (2001) revealed no significant difference in postural balance following 18-minutes of simulated field activities while military subjects wore army chemical protective equipment. Similar findings have been shown in a study investigating the gait characteristics of 19 firefighters walking in heat with their firefighting equipment before and after a 50-min treadmill protocol (Kong, Beauchamp, Suyama, & Hostler, 2010). It was found that falls were more likely to happen as a result of increasing gait variability while subjects were wearing firefighting equipment in the heated room. However, there was no correlation between physiological fatigue with other spatiotemporal gait characteristics and symmetry. It is possible that the high fitness level in these individuals (i.e. soldiers and firefighters) helped lessen the effect of fatigue on their gait and balance control, suggesting that physical conditioning is important in fall prevention.

4.2.2.6 Experience

Working experience has been shown that to be associated with work-related injuries. Polish firefighters who had been employed for less than one year, as well as those who had been working between two to five years, were the groups that were more likely to be injured during work. Although the relationship between fall-related injury and less working experience had not been established, slip, stumble, loss of balance, or fall have been classified as the leading causes of workplace accidents (Szubert & Sobala, 2002). Chi, Chang, and Ting (2005) also found that almost 80% of construction workers who incur fatal fall accidents in Taiwan in 1994-1997 had only worked for less than 1 year. The high rate of fall among new construction workers could be attributed to their inexperience (Hu et al., 2011), as well as their lack of knowledge and awareness about the constructional set up (Lingard & Holmes, 2001).

With more working experience, workers acquire knowledge on how to safely deal with or avoid occupational hazards. The study of Swensen, Purswell, Schlegel, and Stanevich (1992) compared the slipping prevalence among 33 experienced ironworkers and 23 inexperienced university students. Experience could facilitate workers to get familiar with the working environment; hence, they were more likely to detect potential slipping conditions. Furthermore, subjects who were experienced could perform better in perceiving the slipperiness of the underfoot surface, thus applying corresponding modification on gait pattern to compensate the influence of slippery floor (Myung, Smith, & Leamon, 1993).

Besides working experience, many studies had found a positive correlation between occupational accidents and risk perception of injury (Kirschenbaum, Oigenblick, & Goldberg, 2000; Oliver, Cheyne, Tomas, & Cox, 2002; Rundmo, 1992). The workers with past history of injury would be more alert to dangerous and risky situation, thus promote their injury risk perceptions (Harrell, 1990). However, Tsukada and Sakakibara (2016) studied 436 manufacturing industry workers and found that fall history in the last twelve months was a strong predictor of

future falls. It is possible that those who have fallen might have impaired balance control or unsafe work behavior to begin with, which if left undealt with will definitely lead to more falls in the future.

There are also some other interesting results that seem to have contradicted the previous findings. Workers who had been working for six to ten years had higher prevalence in suffering fatal falls from height in the Repair, Maintenance, Alteration and Addition Sector in Hong Kong between 2000 to 2004 (Chan et al., 2008). Nonetheless, Huang and Hinze (2003) reported that those fall incidents generally involved falling from height less than 9.15 meters high and took place mostly at new construction projects with low construction cost. Therefore, the leading cause of those fall-related accidents could be attributed to human judgement error on unsafe condition rather than the workers' experience alone.

4.2.2.7 Safety awareness/behavior

Fall from height among construction workers is often a fatal accident. Several studies have suggested that unsafe behaviors, such as some careless, stupid, misjudged, overconfident or poor work conducts, and lack of knowledge are the reasons that lead to fatal or permanent disable fall-related incidents among construction workers (Lingard & Holmes, 2001; Nadhim, Hon, Xia, Stewart, & Fang, 2016). Similarly, those who have inadequate training about fall (Huang & Hinze, 2003; Lipscomb et al., 2003), lack of relevant skills, safety practice and attitude (Hu, Rahmandad, Smith-Jackson, & Winchester, 2011) or have poor capability, communication skills and tolerance (Nadhim et al., 2016) would experience occupational STF more frequently. As a result, it is important to provide sufficient safety training to the staffs, and have a risk assessment/management team to reduce the potential fall hazards from the employees.

4.2.2.8 Health condition, medication and other substances

Various illness, as well as use of medication or other substance such as drugs and alcohol, can also make an individual more susceptible to STFs. According to Tinetti and Speechley (1989), sensory, cognitive, neurologic or musculoskeletal functions would all be weakened by chronic diseases such as Parkinson's disease, Diabetes and stroke. These pathologies would cause physiological or neurological changes that would disrupt balance control and increase the risk of falling. Furthermore, acute illnesses (e.g. pneumonia) and some medications (e.g. neuroleptic, benzodiazepine, sedatives, antidepressants and antihypertensive) can adversely affect an individual's ability to maintain balance (Gauchard et al., 2001; Tinetti & Speechley, 1989). Besides medication, alcohol consumption can cause delayed vestibular compensatory responses as well as degradation of equilibrium control (Woollacott, 1983). Therefore, it is not surprising to see that alcohol abuse is also a risk factor for falls (Kubo et al., 1989; Ledin & Ödkvist, 1991; Waller, 1978). Though it is not likely that employees in occupational settings would be affected by recreational drugs or alcohol during their work hour, with an aging working population, it is very possible that the workers may be taking medications or have other health conditions that would adversely affect their postural control.

4.2.3 Work-related factors

4.2.3.1 Work pace

In general occupational settings, higher walking pace is often required comparatively to normal gait in order to accomplish tasks faster to promote productivity (Chang et al., 2016). As walking speed is increased, dynamic balance is less stable (Dingwell, Cusumano, Cavanagh, & Sternad, 2001). Moreover, frictional demand and slip initiation risk would also be enhanced with increased walking cadence (Chang, Matz, & Chang, 2012). Chang et al. (2016) also suggested that faster neuromuscular response is needed with faster walking velocity because any error or disturbance would cause greater momentum during falls, placing far greater demands on our sensory and motor systems. As a result, STFs on same level are more likely to occur in occupational settings with higher work pace.

4.2.3.2 Task-related distractions

Bentley and Haslam (2001a) reported that postal delivery officers in the United Kingdom who participated in their study claimed that standing still while reading written address and sorting the mail would increase time cost. The practice of moving to the next delivery stop while reading and sorting mail was a common routine for them, and those in the study's focus group claimed that slipping, tripping and striking accidents happened most frequently in those situations. Up to 40% of the postal delivery officers experienced their fall-related accidents while they were reading and sorting the mail as they were walking. Almost all subjects agreed that these behaviors distracted them from noticing the unsafe environment and fall incidents would then be induced.

In another study, Saari (1984) explained distraction would increase the risk of accidents for workers who need to accomplish tasks in unexpected and unstable surroundings. The need to process additional information places extra demand on one's attention, and they would have less cognitive resources to process sensory information and control their body to maintain dynamic stability. In addition, struggle would be caused by dual-tasks activities, thus creating improper motor responses and loss of balance (Rankin, Woollacott, Shumway-Cook, & Brown, 2000). Rankin et al. (2000) also demonstrated the phenomenon of declined muscle action during the performance of a secondary task in their study. It was shown that the capacity of attention processing was unavailable for controlling balance when dual-task activities were being administered simultaneously. This phenomenon was further exacerbated if subjects were asked to prioritize the secondary cognitive tasks (Rankin et al., 2000), which is often necessary in occupational settings.

4.2.3.3 Urgency of the task

Postal delivery officers in the United Kingdom were urged to finish their work as soon as possible because they were not required to return to their offices after they have completed their tasks (Bentley & Haslam, 2001a). Therefore, they practiced rushing delivery pattern by jogging, skipping or taking unsafe shortcuts in order to reduce time cost. It has been reported that 33% of the officers in the accident-involving group were rushing on a slippery floor while their accidents happened. Such urgency can potentially lead to increased walking speed and place extra demand on the cognitive system (Chang et al., 2016), as well as forcing workers to ambulate as they are working in their mind (i.e. dual-tasking).

4.2.3.4 Shift length

As discussed earlier, fatigue is one of the personal risk factors of STF, yet it can also be discussed in work-related section. Sobeih, Davis, Succop, Jetter, and Bhattacharya (2006) reviewed the influence on balance after 12 hours and 24 hours work shift among firefighters. No significant difference was found on postural sway after either working hours. Courtney et al. (2010) also showed a negative correlation between working hour and risk of slipping. The employees who have less weekly working hours were likely to increase the risk of slipping. This odd observation might be due to unfamiliarity with the working environment as well as the hazardous spots with shorter working shifts. It is also possible that longer work shifts are associated with more sedentary working behavior during their working hours; hence, those workers were exposed to fewer fall hazards when they were moving less. More studies have to be conducted in order to understand the relationship between shift length and fall risks.

4.2.3.5 Load carrying

Gait could be stabilized by arm swinging since walking with arms swing would improve the adjustment of angular momentum of the body and lower the lateral displacement of the Center of Mass (Ortega, Fehlman, & Farley, 2008). Gait stability would be disrupted when workers were carrying load and could not swing their arms naturally. Reducing local dynamic stability has been

shown to be associated with load carrying (Davis, 1983; Liu & Lockhart, 2013). Studies have revealed that females are less stable than males when loaded, and less stability would result when the load was heavier and/or being carried at and above the waist level (Davis, 1983).

It was found that load carrying may lead to increased risk of slip initiation (Liu, Lockhart, & Kim, 2014), as velocity of heel contact and step length were affected when workers were carrying load as low as 10% of their body weight. Contrary, it was also found that low load carrying and altered gait mechanism was not associated with slip propensity (Liu et al., 2014), possibly because friction at the shoe-floor interface would increase with the extra load (Kim & Lockhart, 2008). However, it is important to note that load carrying can often obstruct the visual field of the area in front of the feet. Therefore, people who are carrying load in front of them will be less able to notice slip/trip hazards on the floor directly in front of them.

4.2.4 Management factors

The role of management is essential for workers to avoid STF hazard, especially when they have to work outdoor and unsafe environmental factors were not easy to be expected or controlled (Bentley, 2009). Therefore, along with environmental factors, human factors, and work-related factors, management influence (e.g. project management, safety guidelines and training) has been indicated as the four main factors contributing to occupational STF.

4.2.4.1 Project management

4.2.4.1.1 Project timelines, shift work and urgency of tasks

Varied management practices among organizations have been found to be associated with fall accidents (Nadhim et al., 2016). Falling was the most prevalent type of occupational incident that happened in the Irish Construction industry and most of them were caused by unsafe working practices (O'Reilly, Olomolaiye, Tyler, & Orr, 1994). As unsafe working practices could often be

promoted by assorted project management decisions, such as tight schedule or urgent tasks due to time saving and cost cutting strategies, pressure on their workers would be induced. In order to avoid postponement, pressure of accomplishing the project on time is the dominant factor contributing to the impaired standard of safety on construction workplaces (O'Reilly et al., 1994). Also, the study of Bentley (1998) reported that postal workers agreed that management team often prioritized performance instead of safety to ensure profit. Since postal workers had to complete their tasks within a target time; therefore, safety and management staff would usually accept their workers to take risk and neglect their safety guidelines as long as the goals were achieved (e.g. bringing overweight and too many parcels at a time).

Moreover, various management decisions and work culture could affect workers' hazard perception and cognition, which subsequently lead to increased occupational STFs risk (Bentley, 2009). For instance, long working hours, bad shiftwork roster planning, pressure of productivity and alternative organizational arrangement would intensify the problem of fatigue, working stress and alertness among workers in unsafe occupational environment (Bentley et al., 2006). Bad housekeeping actions can also influence the intrinsic and extrinsic risk factors for occupational STFs. Therefore, in order to effectively lower employees' vulnerability to the risk of occupational STFs, safety management exercises such as providing safety training aimed to raise safety awareness (Bentley & Haslam, 2001a), having proper housekeeping (Kemmlert & Lundholm, 2001), incident inspections (Bentley & Haslam, 2001), as well as injury control procedures and risk assessments (Bentley, 1998; Bentley & Haslam, 2001a) are absolutely essential.

4.2.4.1.2 Smaller companies

Nadhim et al. (2016) stated that varied management was associated with the risk of fall incidents significantly. Small construction companies tended to have higher injury risk than larger companies in many countries; meanwhile, falls and tumbles were the most prevalent causes of workplace injuries (Hon & Chan, 2013). Moreover, workers who worked in smaller enterprises are exposed to greater fall risk and have resulted in more severe fall accidents (Hon & Chan, 2013; Kines & Mikkelsen, 2003) and fatalities (Chi et al., 2005). Increasing risk of fall with reducing

company size might be due to the fact that smaller companies cannot afford safety courses and dedicated employees responsible for safety (Chi et al., 2005), as well as manage the standard of safety practices and guidelines as proper as in large companies (Hon & Chan, 2013; Lipscomb et al., 2003). According to Lingard and Holmes (2001), the standard of occupational safety practices in small construction companies in Australia require major improvement. However, due to limited number of workers and budget, job differentiations in smaller companies would be restricted and insufficient time planning would expose workers to more fall hazards comparatively to those working for larger companies.

4.2.4.2 Safety guidelines

Bentley and Haslam (2001a) listed three safety guidelines (i.e. hazard control, adverse weather practice and safety communication among organizations) that the management teams should consider if they want to reduce occupational STF among their employees.

4.2.4.2.1 Hazard control

Bentley and Haslam (2001a) suggested that most STF accidents could be avoided, such as clearing unnecessary obstacles on walking path in workplace and underfoot construction materials. According to a survey of management safety practices held by Bentley and Haslam (2001a), identifying occupational risk is a task in charged by management team. However, they found that postal delivery officers and their hazard management team had failed to spot and remove potential hazards effectively in unsafe outdoor environments. As a result, 80% of their respondents claimed that outdoor threats, except dogs, were barely addressed to them by their managers.

4.2.4.2.2 Adverse weather practice

Bentley and Haslam (2001a) further suggested that the management team should enforce special safety actions under adverse weather conditions to lower STF accidents for outdoor workers. For example, under unfavorable weather conditions, postal workers should have extra

time for each delivery, alternative transportation mode, or even cancellation of services. Furthermore, special team briefing should be arranged to remind the importance of safety under severe weather conditions.

4.2.4.2.3 Safety communication

Safety communications, as well as effective connection among front-line workers and management team, were indicated as important preventive measures in the study that analyzed the causation and prevention of occupational accidents (Smith & Beringer, 1987). It has been noted that repeated notices about work safety can significantly lower the accident rate among workers (Bentley & Haslam, 2001a). Instead of relying on team briefing in which limited details can be discussed, the management team should promote safety practices and instructions repeatedly in safety meetings, as well as emphasizing the importance of safety-oriented mentality rather than productivity alone.

4.3 *Conclusions*

Risk factors contributing to occupational STF injuries are complicated as the incidents may be the result of a combination of factors regarding diverse occupational components (Bentley & Haslam, 2001a). Key risk factors of workplace STF injuries were summarized under four main categories: environmental, human, work-related and management factors. The occurrence of occupational STF injuries is indeed sophisticated involving a convolution of multiple components among the workplace environment, worker's individual nature, work-related characteristic and management style (Bentley & Haslam, 2001a; Grönqvist, 1995). Therefore, it is extremely important to tackle this problem with a multi-disciplinary approach.

5 Literature review: Existing interventions to prevent occupational slips, trips and falls on same level

5.1 Introduction

The status quo and the risk factors of occupational slips, trips and falls on the same level (STF) have been illustrated in the last three chapters. In order to cope with this serious public health concern which accounts for one of the most if not the most frequent work-related accident both locally and globally, various forms of intervention to prevent slips, trips and falls (STF) will be reviewed in the following paper. Nonetheless, intervention that aims at eliminating environmental risk factors, for examples, installing handrails, grab-bars and applying footwear (Maki & McIlroy, 2006) will not be the focus of this paper. Instead, exercise interventions which target the intrinsic functional risk factors of STF, such as balance ability and physical fitness, will be emphasized. Exercise is a physical activity that is planned, organized and repeated for the purpose of enhancing or maintaining physical fitness, moreover, overall health and wellness (Kylasov & Gavrov, 2011). There is an extensive range of exercise variety, and exercise programmes generally consist of one or combined types of exercise (Sherrington et al., 2019). A single-exercise intervention involves only one dominant category of exercise, while multi-component exercise intervention consists of two or more primary types of exercises that are distributed to all participants in the intervention group (Gillespie et al., 2012). Extensive amount of research on exercise interventions has shown its effectiveness in reducing fall risk among community dwelling elderly people (Gillespie et al., 2012; Sherrington et al., 2019). However, it is important to note that these previous fall prevention studies have focused mainly in the elderly population. Very few studies have investigated the prevention of STF incident through exercise interventions in the younger and/or middle-aged adults in occupational settings. However, it is possible that some of the findings from the older adult studies would be applicable to the working population, as Hong Kong and most developed countries are facing an aging working population phenomenon (Census and Statistics Department of Hong Kong, 2019).

Exercise intervention will be categorized based on the Prevention of Falls Network Europe (ProFaNE) taxonomy that has grouped exercise types into seven main categories (i.e. (1) gait, balance, and functional training; (2) resistance; (3) flexibility; (4) three-dimensional exercise; (5) general physical activity; (6) endurance; and (7) other type of exercises). These classifications allow more than one category of exercise to be involved in a given training programme and it will be classified to the specific training category based on its primary component (Lamb, Hauer, & Becker, 2011). However, no studies have shown flexibility training or other exercises is effective in reducing fall; thus, it will not be discussed in this review.

Additionally, there is an argument about perturbation-based training is more effective than traditional balance intervention in reducing fall (Granacher, Muehlbaue, Zahner, Gollhofer, & Kressig, 2011). Some studies have incorporated slip-simulator and/or virtual reality (VR) platform by applying more advanced technologies in order to facilitate kinetic learning as part of their fall prevention approach (Lockhart, 2010). By familiarizing participants with slip experience through slip-simulators and/or VR platform in a safe and controlled environment, studies have found that participants have reduced slip severity and improved recovery kinematics post-training (Liu, Lockhart, Parijat, McIntosh, & Chiu, 2015; Mirelman, Maidan, Shiratzky, & Hausdorff, 2020; Parijat, Lockhart, & Liu, 2014, 2015). By providing perturbation stimulation, many studies have shown evidence that perturbation-based training has more effective impact than traditional exercise intervention in improving balance recovery ability (Granacher, Muehlbaue, et al., 2011). However, due to the need to the use of specialized equipment and other safety concerns as the participants will be exposed to fall-inducing perturbation, this type of training is neither practical nor safe to be implemented in occupational settings, especially when the training cannot be performed in a well-controlled environment. Therefore, this report will not cover this type of exercise intervention and careful consideration should be given when designing a fall-preventive programme with this approach for the working population.

After eliminating two categories (i.e. flexibility and perturbation-based training) from our review, we noticed that many recent studies have shown that combining (1) cognitive training with

physical training (i.e. dual-task training), or (2) multiple types of physical training (i.e. multi-component exercise) are effective in preventing falls (Goodwin et al., 2014; Sherrington et al., 2019). Therefore, the types of exercise intervention and their corresponding effects in preventing fall to be discussed in this paper are:

1. Gait and Functional Balance Training
2. Resistance Training
3. Three-Dimensional (Tai Chi/Dancing) Exercise
4. General Physical Activity
5. Endurance Training
6. Dual-task Training
7. Multi-component Exercise

5.2 Overall main findings on exercise intervention

Evidence from meta-analyses for the impact of single intervention on reducing the rate of falls in elderly population has been rising in the past decade (Gillespie et al., 2012; Tiedemann, Sherrington, Close, & Lord, 2011). Sherrington et al. (2019) reviewed 81 randomized controlled trial studies (RCTs) that included 19,684 elderly subjects and compared an exercise group with a control group (i.e. the group that received no intervention or intervention that would not affect the study outcome). With high-certainty of evidence, they have found that single exercise intervention was effective in reducing 23% (95% confidence interval (CI), 17% to 29%) of the rate of falls (rate ratio (RaR)= 0.77; 95% CI, 0.71 to 0.83) relative to the control group in 59 studies (N= 12,981). In terms of the number of people who experience at least one post-intervention fall, they were highly certain that exercise could effectively reduce 15% (95% CI, 11% to 19%) of such number relative to the control group (risk ratio (RR)= 0.85; 95% CI, 0.81 to 0.89) after reviewing 63 trials (N= 13,518). Furthermore, exercise could reduce the number of fall-related fracture by 27% (95% CI, 5% to 44%) than without exercise intervention. Such effectiveness seemed to be unaffected whether the studies were exclusive to subjects with high risk of falling or to the general elderly population. To conclude, falls can be reduced by exercise intervention with high certainty of the evidence (Sherrington et al., 2019).

Regarding the types of exercise intervention, perturbation-based training was indicated to be more effective than traditional exercise training in enhancing balance recovery through perturbation stimulus (Granacher, Muehlbaue, et al., 2011). Although the optimal elements of fall-preventive exercise programme are not yet certain, balance exercise alone (Sherrington et al., 2017) and multi-components exercise programmes that consisted of balance exercise (e.g. both strength and balance exercise; Gillespie et al., 2012) have been shown to be especially effective in reducing fall risk. According to a recent systematic review study (Sherrington et al., 2019), balance and functional exercises have significant clinical impact in reducing 24% (RaR= 0.76; 95% CI, 0.70 to 0.81) of the rate of falls compared with the control groups with high certainty of the evidence based on 39 RCTs (N= 7,920). Moreover, the number of fallers who experienced at least one fall

declined by 13% (RR= 0.87; 95% CI, 0.82 to 0.91; 37 RCTs; N= 8,288) after receiving their exercise intervention with high certainty of the evidence.

With moderate certainty of the evidence (Sherrington et al., 2019), multi-component exercise intervention (i.e. generally consists of a combination of functional balance and resistance training) was effective in lowering the rate of falls by 34% (RaR= 0.66; 95% CI, 0.50 to 0.88; 11 RCTs; N= 1,374) and the number of people who experienced at least one fall by 22% (RR= 0.78; 95% CI, 0.64 to 0.96; 17 RCTs; N= 1,623). Gillespie et al. (2012) also verified the effectiveness of multi-component exercise training and found that the rate of falls reduced significantly by 29% (RaR= 0.71; 95% CI, 0.63 to 0.82; 16 RCTs; N= 3,622) and risk of falling by 15% (RR= 0.85; 95% CI, 0.76 to 0.96; 22 RCTs; N= 5,333). Meanwhile, multi-component home based exercise training reduced 32% of the rate of falls (RaR= 0.68; 95% CI, 0.58 to 0.80; 7 RCTs; N= 951) and risk of falling by 22% (RR= 0.78; 95% CI, 0.64 to 0.94; 6 RCTs; N= 714). Donath et al. (2015) indicated that multi-component exercise training was effective in lowering the risk of falling by 15%, regardless of home- or group-based intervention.

Tai Chi has been shown to be effective in reducing both fall risk and fall prevalence. After practicing Tai Chi, the risk of falling has been reduced significantly by 29% (RR= 0.71; 95% CI, 0.57 to 0.87; 6 RCTs; N= 1,925; Sherrington et al., 2019). Furthermore, rate of falls has been reduced by 19% (RaR= 0.81; 95% CI, 0.67 to 0.99; 7 RCTs; N= 2,655; low-certainty of evidence; Sherrington et al., 2019) to 28% (RaR= 0.72; 95% CI, 0.52 to 1.00; 5 RCTs; N= 1,563; Gillespie et al., 2012), resulting in 20% less people who experienced falls (RR= 0.80; 95% CI, 0.70 to 0.91; 8 RCTs; N= 2,677; high certainty of evidence; Sherrington et al., 2019). On the other hand, due to limited supporting evidence, the effectiveness of primarily resistance, dance, or walking exercises on fall-related outcomes relative to the control groups remained inconclusive.

Other than the type of exercise intervention, group-based exercises have been demonstrated to be more effective in reducing fall rate, as well as enhancing balance and quality of life relative

to the control group, as the participants in group-based exercises have higher satisfaction and adherence (Martin et al., 2013). However, when compared with physical therapist-prescribed home exercise programme, group-based exercises do not have added benefit in reducing fall rate, though the improvements in some quality of life and physical functioning measures remained significant (Martin et al., 2013). On the other hand, Clemson, Mackenzie, Ballinger, Close, and Cumming (2008) determined that home-based modification was successful in decreasing the rate of falls when compared with alternative environmental settings, possibly due to increased adherence. As expected, exercise intervention trained by health professionals, such as physiotherapists, has larger impact than in those delivered by trainers who were not health professionals (e.g. a physical trainer), though both groups were effective in lowering the rate of falls (Sherrington et al., 2019).

5.3 *Types of exercise intervention*

5.3.1 *Gait and functional balance training*

This category consists of three diversities of exercise intervention, which includes gait, balance and functional exercise. According to the definition of the ProFaNE taxonomy (Lamb et al., 2011), gait training consists of particular correction of walking movement (e.g. walking posture, stride length and cadence), adjustment of pace, as well as direction. Balance training covers the dynamic change of bodyweight from one part to the other part of the body or confronts specific aspects of balance system, e.g. vestibular system. There are various types of balance retraining activities, including not only the education of essential fundamental movement pattern, but also a diverse range of dynamic movements that aims at different level of balance under assorted circumstances. Functional training applies functional exercises as the training stimulant; moreover, it is based on the theoretical conception of particular task. Lamb et al. (2011) suggested that all gait, balance and functional exercise should be customized in response to an individual's balance ability. Assessments should be conducted before designing the intervention in order to evaluate the capability of the subjects. In addition, principle of progression should to be applied to modify the exercise programme as the abilities of the participants improve over time. Examples of gait, balance and functional exercise are walking in different direction, turning, bending, ball exercise with coordination and reaction activities, standing on unstable surface, walking lines and static/dynamic balance exercise.

Sherrington et al. (2019) reviewed 39 RCTs (N= 7,920) that evaluated falls prevention with community-dwelling older people using gait, balance and functional exercises as the primary intervention versus control groups. With high certainty of evidence, they revealed that such intervention was effective in reducing 24% of rate of falls (RaR= 0.76; 95% CI, 0.70 to 0.81), resulting in 13% less people who experienced at least one fall (RR= 0.87; 95% CI, 0.82 to 0.91) when compared with the control groups. Other than Sherrington et al. (2019), DiStefano, Clark, and Padua (2009) also reviewed 16 articles systematically to assess the effectiveness of balance training in enhancing balance capability among the healthy aging population. Balance training

was proved to be effective in improving static balance ability on stable and unstable surfaces, as well as dynamic balance ability with strong evidence support. The outcome was concluded from consistent findings of various studies with strong designs. This review paper further indicated that the type of balance training do not affect the competence to achieve balance improvement as the training exercise conducted by the reviewed studies generally included dynamic exercises with lower extremity and trunk perturbations, balancing with instrumented stability systems, single-leg stance on unstable platforms (e.g. tilted board, wobble boards and ankle discs), or multifaceted training with balance exercise as the primary component and combined with strengthening, plyometric and agility exercises.

Regardless of the exact mode of balance training, principle of progression has been applied in many of the effective studies in which the balance exercise intervention progressed regularly from eyes open to eyes closed, double-leg stance to single-leg stance as well as firm stable surface to unstable surface such as foam (DiStefano et al., 2009). Moreover, some dynamic progressions were carried out, for instance, kicking an elastic band with the non-dominant leg and moving body to cause a disturbance to the center of mass. Among the 16 reviewed studies, 14 of them illustrated balance improvement after the intervention (DiStefano et al., 2009). The two remaining articles failed to indicate improvement in static balance possibly because of their highly capable participants. A ceiling effect may be developed when the balance measuring tasks are too easy to achieve; thus, it is difficult to discover the differences between pre- and post-intervention (Holm et al., 2004; Kovacs, Birmingham, Forwell, & Litchfield, 2004).

Most of the balance exercise training studies focused on the elderly population. For example, in a relatively larger-scaled RCT study, Cornillon et al. (2002) evaluated the performance of a 10-week balance exercise programme among 303 community dwelling older adults with a mean age of 71. The exercise programme consisted of gait, balance, coordination and sensory training as major exercise intervention, as well as supplemented with some muscular training activities. There was no significant difference in terms of the rate of falls among the two groups while the rate ratio was 0.82 (95% CI; 0.58 to 1.17). However, intervention group performed significantly better ($p <$

0.001) in single leg standing balance test with eyes closed after training. Moreover, the incidence rate of falls was lower than the control group even though there was no significant statistical difference ($p = 0.32$) after one year in the follow-up assessment.

Another large-scale functional balance intervention study was conducted by Gawler et al. (2016) with 1,256 community-dwelling older adults. They examined the efficiency of a 24-week group-based exercise programme (Falls Management Exercise, or FaME) and a 24-week home-based exercise programme (Otago Exercise Program, or OEP) relative to a control group (Usual Care, UC) in promoting moderate to vigorous physical activity (MVPA) and preventing fall and fall-related injuries. The FaME group was required to participate in a one-hour supervised session once a week, as well as 30-minute home-based exercise programme twice a week. FaME combined various components of falls management strategies aiming at increasing balance, functional capacity, bone and muscle mass, as well as balance confident (Skelton & Dinan, 1999). Specifically, it included dynamic posture training, coordination and gait training, and strengthening of selected muscle groups. Through these balance training, FaME focused on enhancing overall fitness (e.g. lower and upper limbs strength, postural alignment, gait technique, functional ability through progressive resistance and flexibility training, dynamic balance, sensory input, multisensory skills, etc.) of the participants progressively. On the other hand, the OEP group was asked to perform 30-minute home-based exercise thrice a week. OEP is a training programme which primarily consisted of balance retraining exercises (i.e tandem stance; tandem walk; walking on the toes and heels; walking backwards, sideways, and turning around; stepping over an object; bending and picking up an object; stair climbing in the home; rising from a sitting to standing position; knee squat; and ‘active range of movement’ exercises, such as neck rotations and hip or knee extensions), as well as muscle strengthening exercises (including hip extensor/ abductor muscles, knee flexor/ extensor muscles, inner range quadriceps, ankle plantar and dorsi-flexor muscles), and a walking plan as secondary intervention (Campbell et al., 1997).

In general, FaME was more effective than OEP in reducing falls in older adults as FaME participants had significantly lower rate of falls relative to the control group (IRR= 0.74; 95% CI,

0.55 to 0.99; $p=0.042$). Injurious falls in the FaME group were also significantly lower than that of the control group in post-training (IRR= 0.55; 95% CI, 0.31 to 0.96; $p=0.04$) and 12 months after the completion of the training (IRR= 0.73; 95% CI, 0.54 to 0.99; $p=0.05$). Although the positive effect of FaME did not last 24-month after the completion of intervention, the FaME subjects who maintained 150 weekly minutes of MVPA fell significantly less even 2 years after the completion of the intervention (IRR= 0.49; 95% CI, 0.30 to 0.79; $p=0.004$) when compared with the FaME participants who did not maintain the minimum PA recommendation by the World Health Organization. OEP, on the other hand, only had a modest and non-significant decline in the rate of falls (IRR= 0.76; 95% CI, 0.53 to 1.09; $p=0.14$) relative to the control group. Contrary, Robertson, Campbell, Gardner, and Devlin (2002) showed that OEP was effective in reducing both the number of fall (IRR= 0.65; 95% CI, 0.57 to 0.75) and injurious fall (IRR= 0.65; 95% CI, 0.53 to 0.81) among those who are aged over 80 with or without previous fall history. Such difference can be attributed to the fact that OEP was designed for more frail older adults.

Can younger adults who do not have balance impairment be benefited by balance training? Two studies have investigated the effect of neuromuscular training intervention on elite skaters (Kovacs et al., 2004) and handball players (Holm et al., 2004). The skaters in the neuromuscular training group were asked to perform progressive exercises including single-leg stance, wobble board and trampoline balance exercises for 20-25 minutes, 3 times a week for 4 weeks (Kovacs et al., 2004), whereas the handball players performed progressive floor exercises (from planting, to cutting, and to jumping and landing), as well as wobble board and balance mat exercises (from two legged stance, to single leg stance, and to multi-person) for 15 minutes, either 3 times a week for 5 weeks or once a week for 7 weeks (Holm et al., 2004). There was no significant improvement in static balance ability on a stable surface in both studies, possibly due to ceiling effect as discussed earlier; however, participants engaged in neuromuscular training programme showed significant improvement in static balance ability on unstable surfaces for the skaters (Kovacs et al., 2004), as well as in dynamic balance for the handball players both immediately post-training and in one-year follow-up (Holm et al., 2004).

In summary, it has been proved that even elite athletes could also be benefited by balance training, though the training difficulty must be challenging for their abilities. For instance, if OEP was used to train the elite athletes or healthy young adults, they will not receive any improvement in their balance ability. Another important take home message is that these studies indicated that ceiling effect in balance assessment will likely occur with elite athletes or even healthy population who do not have balance impairment to begin with. Therefore, it is necessary to have more challenging assessment tasks in order to show the improvement of balance control.

5.3.2 *Resistance training*

Resistance training includes all exercises that involve weight training while muscle contracts against a level of resistance to the stage of overload and develop a training effect that benefits the muscular system (Lamb et al., 2011). The resistance could be an individual's own bodyweight or external loads like free weights or weight machines. Before any resistance training is implemented, assessment is needed to evaluate the ability of the participants in order to design a customized resistance training programme. As subjects' ability will improved over time, progression of the programme must be adjusted accordingly (Lamb et al., 2011). In the early stage of resistance training, individual's own bodyweight or Thera-band can act as external load, while exercising on weight machines and lifting free weights are for the more advanced individuals. Some functional trainings with excessive weight (e.g. heavy shopping bag, filled water bottle) can be categorized as resistance training as well (Lamb et al., 2011).

Referring to Sherrington et al. (2019), the effectiveness of resistance training on reducing falls remains uncertain. They determined that the findings on the rate of falls and numbers of subjects who experienced falls were based on very low certainty of evidence. Moreover, not only the fall-related statistic was unclear, but the effect of resistance training on balance performance was also questionable (Sherrington et al., 2019). Similar conclusion was also reached by Latham, Bennett, Stretton, and Anderson (2004), as they failed to see any distinctive outcome (effect size= 0.11) on numerous measurements of standing balance in 789 subjects after resistance training

intervention. Likewise, Latham et al. (2003) believed that a programme consists of strength training alone could not deliver fall-preventive effect. However, although evidence is limited in proving strength training could enhance balance ability, the risk of suffering fall-related bone fracture was shown to be diminished in multiple studies (Liu-Ambrose, Khan, Eng, Heinonen, & McKay, 2004; Suominen, 2006). Such contradictory findings may be explained by the high variability in subjects' physiological status, differences in training mode, frequency, intensity and duration, as well as the muscle groups involved in different studies.

Generally speaking, resistance training used in RCTs as fall intervention often involved strength training with moderate volume that is equivalent to eight to twelve repetitions per set, two to three sets per exercise, and performed at least twice per week (Cadore, Pinto, Bottaro, & Izquierdo, 2014; Donath, van Dieën, & Faude, 2016). Strength training exercises are usually accomplished at moderate to high intensity at around 60 to 80% of one repetition maximum (1 RM; i.e. the maximum load that can be lifted only once) (Granacher, Gruber, & Gollhofer, 2009). Granacher et al. (2009) investigated whether traditional resistance training could make a difference on strength performance and postural balance in seniors. Strength training with heavy resistance (80% of 1RM) was performed twice a week for 13 weeks. Performance of their muscle strength assessment, as well as their scores on static postural control (i.e. functional reach test) and dynamic postural test (i.e. tandem walk test) were significantly improved after 13 weeks of training; however, there was no significant effect on their capacity to restore postural balance from platform perturbations. Similar findings have also been reported in a systematic review (Granacher, Gollhofer, & Strass, 2006).

When experiencing a sudden fall threatening situation in real life (e.g. after a slip/trip), producing explosive power to take a step or grasp a nearby object rapidly is essential in recovering balance (Pijnappels, Bobbert, & van Dieën, 2005). The significance of traditional strength training is doubtful in enhancing explosive force production (Donath et al., 2016). In response, Porter (2006) pointed out that high-velocity and power training perform better in improving explosive force production capacity rather than strength training with heavy load. Besides having added

benefit in improving the rate of force development, muscle power training also yielded better physical functional test performances than traditional strength training (Miszko et al., 2003). Miszko et al. (2003) investigated the effectiveness of a 16-week power as well as strength exercise programmes among seniors. All subjects exercised three times a week using progressively heavier load of 50% to 70% of 1RM over the first 8 weeks. After week 8, the strength group stayed at 80% of 1RM until the end of intervention. The programme of the power group was changed to develop muscle power with 6 to 8 repetitions for three sets at 40% of 1RM. More importantly, concentric movements were required to be performed as fast as possible. Results illustrated that both groups successfully enhance maximal strength equally. Nonetheless, relative to the strength training group, power training group had greater improvement in their physical functional capacity which included components of balance, coordination and muscle endurance (e.g. 6-meter walk test, floor rise to standing test and repeated chair rise test). Henwood and Taaffe (2005) did a similar study with a high-velocity resistance training twice a week for 2 months. Supporting the findings of Miszko et al. (2003), they also found that physical performance (e.g. 6-meter walk test, floor rise to standing, repeated chair rise, and lift and reach test) was significantly improved in the high-velocity resistance training group.

To investigate the optimal intensity to be used in muscle power training, Orr et al. (2006) conducted a 10-week high-velocity power training study with three different groups: (1) low-intensity (20% of 1RM), (2) medium-intensity (50% of 1RM) and (3) high-intensity (80% of 1RM). Healthy elderly people were recruited as subjects and they were required to exercise twice a week for 10 weeks. The low-intensity group enjoyed the biggest balance improvement among all senior subjects; therefore, applying low load power training on alternative balance-related intervention may maximize its effectiveness (Orr et al., 2006).

In summary, high-velocity power training contributes to maximal strength as well as causes a positive transfer effect to enhance balance capability with a low-intensity load (Granacher, Muehlbaue, et al., 2011). Nevertheless, most of the findings were based on the studies that focus on community dwelling older adults, the outcome of implementing these results for the purpose of

improving balance performance in other target population, such as working labor, remains uncertain. Previous study has shown that low-intensity resistance training can also yield significant physiological changes (i.e. increased muscular size) leading to increased strength even in young adults (Tanimoto et al., 2008), suggesting that low-intensity resistance training may be a possible mode of training muscles even in occupational settings.

5.3.3 Three-dimensional (Tai Chi/dancing) exercise

Three-dimensional training consists of continual movement in a controlled, flowing and repetitious way through all three spatial planes or dimensions (i.e. forward and back, side to side, and up and down) (Lamb et al., 2011). Tai Chi, the most common example of 3D exercise in fall preventive training, and Qi Gong contain the elements of weight transference, upright position, subtle shift of head position and gaze direction. Dance, on the other hand, covers of a wide diversity of dynamic movement nature, tempo and patterns (Lamb et al., 2011).

To-date, no study has investigated the effect of 3D exercise on fall prevention in occupational setting, but there are several systematic reviews (del-Pino-Casado, Obrero-Gaitán, & Lomas-Vega, 2016; Hu et al., 2016; Low, Ang, Goh, & Chew, 2009; Sherrington et al., 2019) that have examined the efficacy of Tai Chi in fall prevention among community-dwelling older adults. Comprehensive researches have been conducted to evaluate whether Tai Chi is an effective fall preventive exercise. While some RCT studies showed that Tai Chi has no significant impact in improving physical functioning (Wolf, Barnhart, Ellison, Coogler, & Group, 1997; Woo, Hong, Lau, & Lynn, 2007) and reducing the number of fall (Logghe et al., 2009; Taylor et al., 2012; Woo et al., 2007), the general consensus is that Tai Chi can effectively reduce fall risk in older population, as indicated by multiple large scale systematic review and meta-analysis papers (del-Pino-Casado et al., 2016; Hu et al., 2016; Sherrington et al., 2019), given that the elderly participants were comparatively young and healthy (Low et al., 2009). For example, Hu et al. (2016) found that Tai Chi can reduce the fall risk significantly (odds ratio= 0.70; 95% CI, 0.59 to 0.84; N= 2,850) in their systematic review and meta-analysis paper. Likewise, del-Pino-Casado et al. (2016) reviewed 13 RCTs and

showed that Tai Chi could lower the risk of falling significantly (absolute risk reduction= 0.10; 95% CI, -0.06 to -0.15). With lowered risk of fall, Sherrington et al. (2019) have reported a 19% decline in the number of actual fall (RR= 0.81; 95% CI, 0.67 to 0.99; 7 RCTs; N= 2,655; low certainty evidence) and 20% reduction in the number of people who experienced at least one fall (RR= 0.80; 95% CI, 0.70 to 0.91; 8 RCTs; N= 2,677; high certainty evidence). The authors of these systematic reviews and meta-analyses noted that there is a wide variety of forms of Tai Chi and it is necessary to conduct further studies on exercise intensity, duration, frequency, as well as with different populations other than older adults in order to fully understand the impact of Tai Chi as a form of fall-preventive exercise (Hu et al., 2016).

Previous studies have shown that practicing Tai Chi three times a week for half year can lead to significant less fall incidence (Li et al., 2005). Moreover, practice Tai Chi can lead to significant improvement in functional balance (i.e. Berg Balance Scale, Dynamic Gait Index, Functional Reach, and single-leg standing), physical performance (i.e. 50-foot speed walk and Timed-Up-&-Go Test), as well as reduction in fear of falling post-training (Li et al., 2005). Furthermore, such benefits were retained even half year after the end of the intervention period (Li et al., 2005). However, is it necessary to do face-to-face training to gain the benefits of Tai Chi exercise? To answer that question, Wu, Keyes, Callas, Ren, and Bookchin (2010) compared the effects of three different bases of Tai Chi training programmes (i.e. telecommunication-based, Tele-ex; community center-based, Comm-ex; and home video-based, Home-ex). Subjects in all 3 groups practiced similar 24-form Yang-style Tai Chi 3 hours a week for 15 weeks. However, only the Tele-ex and Comm-ex groups showed significant improvement in their functional balance (i.e. single-leg stance time, body sway during quiet stance, Timed-Up-&-Go test) and balance confidence (Activities-specific Balance Confidence), resulting in less falls. Possibly, these two groups enjoyed significantly better improvements because of their higher adherence and practice time than the Home-ex group (Wu et al., 2010). As a result, it is important to remind participants to follow the exercise prescription if face-to-face exercise programmes cannot be administered.

Given the success of Tai Chi training interventions for older adults, some studies have investigated whether similar benefits can be achieved in younger or middle-aged adults. Two studies have examined the benefits of Tai Chi on sedentary middle-aged women. In the first study, it has been found that practicing Tai Chi 3 times a week for 12 weeks led to significant reduction in blood pressure and improvement in dynamic balance as measured with the Functional Reach test (Thornton, Sykes, & Tang, 2004). Similarly, the second study found that sedentary middle-aged women in their study had significant reduction in fat and lowered heart rate after practicing Tai Chi twice a week for 6 months (Noor Aini et al., 2012). Unfortunately, despite some positive results from numerous Tai Chi studies, the precise effect of Tai Chi on middle-aged adults' balance ability remained uncertain as many of the results for this age-group came from studies with low methodological quality (Zheng et al., 2015).

Besides Tai Chi, dance is also a common type of 3D exercise trainings; however, the number of study that evaluated the effectiveness of dancing for fall prevention is limited. Because of inadequate evidence, the effectiveness of dance training on fall prevention remained uncertain (Sherrington et al., 2019). In one RCT study that investigated the impact of dance training for fall prevention, the authors failed to show significant difference on functional balance and fall statistics after the intervention group did social dancing (folk or ball room dancing) twice a week (1 hour per session) for 12-months (Merom et al., 2016). One possible explanation is that in order to engage in social dancing, the participants must have relatively intact balance control. As a result, these individuals might have low fall risk to begin with. Engaging frail older adults with high fall risk in dance intervention may be dangerous as these people will actually be exposed to increased slip, trip and fall hazards. Another logical explanation for the lack of significant effect is that the type of dance used in this study may not have sufficient intensity to bring forth the benefits for fall prevention (Merom et al., 2016).

Dance intervention has also been used in another study involving middle-aged women (Kostić et al., 2015). A total of 34 hours of Greek folk dancing (3 hours per week) was administered to the participants in the dance intervention group in which slow tempo was used as a warm up and

alternating moderate and fast tempos were used during the main phase of each training session. The study showed that even for middle-aged women, dancing with moderate to high intensity could have significant positive effect on both static and dynamic balance. As a result, it is possible that dancing can be a form of effective fall preventive exercise, though the type of dance, as well as the intensity or tempo of dance, will play a determinative role in the outcome of the training (Merom et al., 2016).

In summary, there is little doubt that Tai Chi is an effective form of fall preventive exercise for the elderly population as multiple large scale RCTs, systematic reviews and meta-analyses have demonstrated that it can significantly improve functional balance and reduce fall incidence (del-Pino-Casado et al., 2016; Hu et al., 2016; Sherrington et al., 2019). Though it is possible that younger or middle-aged adults can also be benefited with various forms of 3D exercise intervention such as Tai Chi and/or moderate-to-high tempo dancing, more well-designed studies have to be conducted to verify such hypothesis.

5.3.4 *General physical activity*

Physical activity (PA) is defined as “any bodily movement that produced by skeletal muscle contraction resulting in a substantial increase in energy expenditure” (Lamb et al., 2011). PA includes all activities that consist of occupational, transportation and recreational components, and it can also contribute to individual’s health as well as enhancing health attitudes, health habits and lifestyle (Lamb et al., 2011). There are a wide range of PA, such as indoor and outdoor walking, cycling, playing tennis and swimming. PA is practical to everyone and beneficial to our health; however, it is not a very common mode of intervention and its impact on fall prevention is questionable. Sherrington et al. (2019) reviewed two RCTs targeting community dwelling elderly people and concluded that general PA intervention led to a 14% increase (RaR= 1.14; 95% CI, 0.66 to 1.97) in the rate of falls and 5% increases (RR= 1.05; 95% CI, 0.71 to 1.54) in the number of people who experienced one or more fall than control group with low certainty due to the limited sample size.

In one of the studies, Voukelatos et al. (2015) investigated the effect of a 48-week walking programme in elderly adults as they realized walking is the most popular and approachable form of PA. In fact, walking is prescribed as a supplementary exercise in the Otago Exercise Programme (OEP) that has proven effectiveness in reducing fall (Robertson et al., 2002), functional capacity and physical performance (Dadgari et al., 2016). Every subject walked at self-selected pace and progressive increase their walking plan. The walking programme effectively increased the PA level of the participants; however, the intervention group had no difference in the rate of falls compared with the control group in the follow-up period (IRR= 0.88; 95% CI, 0.60 to 1.29). Therefore, leisure walking alone is not an effective fall-preventive intervention. This is understandable as the low intensity of walking exercise cannot provide the required stimulations to trigger significant muscle and bone growth. Therefore, it was advocated that walking should be excluded from various forms of fall preventive interventions as walking by itself increases exposure to fall risk for frail older adults (Tiedemann et al., 2011).

In summary, it is possible that other forms of general PA with higher intensity may have some benefits in reducing falls or fall risks for older adults, though such evidence is lacking in the current scientific community. Furthermore, most people in the working population are already exposed to a certain level of general PA through their work and commute, they definitely will require other modes of training in order to further reduce their fall risk in occupational settings.

5.3.5 *Endurance training*

Endurance exercise focuses on cardiovascular conditioning while it is aerobic in nature as well as promoting heart rate and blood circulation to the heart simultaneously. Jogging, interval training, cycle ergometer and rowing machine are the examples of endurance training (Lamb et al., 2011). Study using endurance exercise as the primary or sole intervention to prevent fall could not be found; however, Buchner et al. (1997) investigated the effect of strength and endurance

training on gait, balance and fall risk in community-living older adults for 24-26 weeks. Subjects were randomly assigned in two exercise training groups (i.e. strength training using weight machine and endurance training using bicycle) and a control group. However, no significant effects were found on gait, balance, or risk of falling by the endurance training group. More studies are needed in evaluating the effectiveness of endurance training, for the younger, middle-aged, and older adult populations.

5.3.6 *Dual-task training*

Dual-task exercise was one of the various types of intervention that has been used to prevent falls in recent years. For fall prevention, the primary task often involves balance or gait training, and subjects were usually asked to perform a secondary cognitive task simultaneously. Dual-tasking, as known as multi-task, refers to the simultaneous performance of at least two tasks that could also be implemented separately (McIsaac, Lamberg, & Muratori, 2015). It would affect the performance of the primary task while the secondary task was carrying out comparatively to single-task efficiency. Dual-tasking is typical in our daily life as competence of dual tasking is always required in order to accomplish our daily activities, such as applying our cognitive resources (e.g. talking or texting on mobile phone) while we are walking to mediate complicated environmental conditions (Dorfman et al., 2014). Dual-tasking is also very common in occupational settings. For example, postal delivery officers often try to save time by ambulating to the next delivery stop while reading and sorting mail at the same time (Bentley & Haslam, 2001). As a result, it has been claimed that up to 40% of the fall accident during mail delivery occurred when cognitive resources and visual attention was directed away from balance or gait (Bentley & Haslam, 2001).

Traditionally, gait, specifically to the healthy young population, was believed to be substantially a fully automatic task that variation of gait (e.g. walking speed and direction) could be made almost effortlessly whenever it is necessary (Bayot et al., 2018). However, both balance and gait actually requires some cognitive processing. Aging is often accompanied by reduced cognitive capacity; thus, gait quality of older adult may be impaired when there are extra cognitive

demands or situation with different degrees of complexity, leading to increased risk of falling (Bayot et al., 2018; Dorfman et al., 2014). Although the relationship between cognition and motor control remains uncertain, approaches of cognitive-motor dual tasks were studied in order to improve the prevention of cognitive impairment as well as falls (Bayot et al., 2018).

Many recent dual-tasking studies have shown that gait speed often decrease significantly with the addition of a secondary cognitive task. Studies have shown that performing concurrent attention demanding tasks (i.e. verbal fluency task) caused significant reduction in walking speed and increase in stride time variability (Dubost et al., 2006). Furthermore, as the complexity of the secondary task increases, the slower the gait speed would become. Besides gait speed, cadence, stride time, and gait stability would all be adversely affected during dual-tasking scenario (Smith, Cusack, Cunningham, & Blake, 2017). Numerous studies have suggested that performance of gait is prone to dual-tasking due to intrinsic interfering factor rather than extrinsic interfering factor, and elderly people are more affected than healthy young adults due to their decreased cognitive capacities (Al-Yahya et al., 2011). Under dual-tasking situations, strong correlations were found between age and gait speed reduction, as well as between the level of cognitive state and gait speed reduction among healthy subjects. Gait speed was determined as an ordinary indicator of functional performance (Hardy, Perera, Roumani, Chandler, & Studenski, 2007) and a positive relationship has been showed between decreasing walking speed during dual tasking and recurrent fall among elderly people (Beauchet et al., 2008). As a result, it is obvious that the control of rhythmic stepping of walking was not entirely an automatic mechanism as previously thought, but requires a certain degree of attentional control especially in older adults. While decreasing gait qualities (i.e. gait speed) (Beauchet et al., 2008) and increasing stride time variability (Hausdorff, Rios, & Edelberg, 2001) were showed to be significantly associated with growing risk of fall in the elderly population, more large-scale studies are needed to examine the exact effectiveness of dual-task interventions in preventing falls.

Most of the dual-task fall intervention studies to-date was performed with older adults. For example, one dual-task study has investigated the effectiveness of a 6-week dual-task treadmill

training intervention for fall prevention (Dorfman et al., 2014). Subjects were asked to walk on a treadmill 3 times a week. Base on each subject's natural gait speed, the speed on the treadmill would increase progressively week-by-week. Motor difficulty was built up by reducing hand support to one hand in week 4 to 5, and no hand support in week 6. After 5 minutes of pure walking, three varieties of cognitive tasks would be introduced: (1) phoneme monitoring (i.e. listening to a short story and answering some informative questions at the end), (2) arithmetic tasks (i.e. calculating some simple mathematic questions) and (3) verbal fluency tasks (i.e. generating semantic and phonetic lists of words). Similar to how they adjusted the walking speed and motor difficulty, the difficulty of the cognitive task increase progressively base on their performances. After 18 sessions, their balance control (i.e. Berg Balance Scale), gait control (i.e. Dynamic Gait Index), walking speed (i.e. both single- and dual-task walking), cognitive performance (i.e. Trail Making Test B), quality of life (i.e. SF-36) and physical activity level (i.e. PASE) all showed significant improvement (Dorfman et al., 2014). Such compelling results suggested that dual-task training should be included into future fall-preventive interventions.

Scientists have also investigated other forms of secondary task in dual-task training. Instead of the commonly used secondary cognitive task, an interesting study has examined the effectiveness of using of a secondary motor-interference task during balance training for older adults in improving gait stability (Granacher et al., 2010). While performing the primary task of balancing on unstable surfaces, subjects were also asked to simultaneously perform a motor-interference task such as catching and throwing a ball. The difficulty of task, number of sets, and duration of training gradually increased over the 18 training sessions to be completed in 6 weeks. The subjects' gait pattern was assessed on an instrumented walkway in single-, dual- (walking+ motor/cognitive), or triple-task (walking+ motor + cognitive) conditions both pre- and post-training. Results revealed that using a motor-interference task during balance training effectively improved gait stability (i.e. reduced gait variability) (Kressig, Herrmann, Grandjean, Michel, & Beauchet, 2008) only during single-task but not during dual- or triple-task conditions (Granacher et al., 2010). Furthermore, such training led to improvement only of the motor task and not the cognitive task during dual-task conditions. The improvement on only the motor task but not the walking task during dual-task situation suggested that the subjects might have prioritized the

performance of the motor task over the balance task during their training. As a result, it may be important that the subjects should be instructed to focus their attention on the primary balance task rather than the secondary task during their dual-task balance/gait training to achieve the greatest effect for fall prevention.

Silsupadol et al. (2009) conducted an interesting study on community-dwelling older adults to investigate ways to optimize the effectiveness of dual-task training through specific instruction on task prioritization. In their study, they examined the difference between single-task versus dual-task balance intervention with fixed-priority or variable-priority instructions. The physical training consisted of a variety of balance exercises such as standing with eyes closed and tandem standing. For the dual-task condition, subjects were asked to simultaneously perform a cognitive task such as a calculation task or an object naming task. Furthermore, for the dual-task groups, subjects in the fixed-priority instruction sub-group were asked to maintain attention on both the postural and cognitive tasks equally at all time; while the variable-priority sub-group was asked to spend half of the sessions focusing on the balance task alone and the other half only on their cognitive task performance. All participants were trained three times a week for 4 weeks. In the post-assessment, all subjects had significantly increased their single-task gait speed; nonetheless, only the dual-task groups had significant improvement in their dual-task walking performance. Furthermore, the variable-priority dual-task sub-group had sustained improvement at their 12-week follow-up assessment. Therefore, besides having progression in difficulty, it is extremely important to have variable-priority to maximize the effectiveness of dual-task fall prevention training (Silsupadol et al., 2009).

In summary, Beauchet et al. (2008) suggested that an effective fall-preventive intervention programme should consist of dual-task exercise due to gait instability would increase the risk of falling while attention was disrupted or multi-tasks were performed at the same time. This is especially common in occupational settings when individuals are often ambulating while attending other cognitive and/or motor tasks simultaneously (e.g. a waiter balancing a food tray while thinking where to deliver the food/drink as he/she is walking on a slippery surface in a clustered

environment). Therefore, dual-task training with progression on both the motor and cognitive tasks should be incorporated as one of the components of an effective fall-preventive intervention programme (Dorfman et al., 2014).

5.3.7 *Multi-component exercise*

Multi-component exercise composes of two or more different modes of exercise interventions in preventing falls. Generally speaking, most of the current RCTs have a combination of balance and functional exercises with resistance training. Similar to other fall prevention studies, most of the published RCTs were targeting older adults (Goodwin et al., 2014; Sherrington et al., 2019). Sherrington et al. (2019) reviewed 21 RCTs investigating the effectiveness of multi-component exercise intervention in preventing falls in 2019. They have found that in contrast to the control group, multi-component exercise intervention led to a reduction of 34% (95% CI, 12% to 50%) in the number of falls (RaR= 0.66; 95% CI, 0.50 to 0.88; 11 RCTs; N= 1,374) and 22% (95% CI, 4% to 36%) in the numbers of people who experienced one or more fall (RR= 0.78; 95% CI, 0.64 to 0.96; 17 RCTs; N= 1,623). Goodwin et al. (2014) showed that multi-component exercises contributed to both a decline in fall rate (pooled rate ratio= 0.80; 95% CI, 0.72 to 0.89) as well as the number of people who experienced a fall (pooled risk ratio= 0.85; 95% CI, 0.80 to 0.91) when compared with the control groups who received no intervention (17 RCTs; N= 5,034). Both systematic reviews indicated that there were moderate certainty of evidence to support multi-component exercise intervention could possibly reduce the rate of falls and the number of fallers. However, another research suggested that the efficacy on fall prevention was uncertain when a comparison was made between multi-component exercise intervention and other single type of exercise intervention (Fusco, 2019). Moreover, there was inadequate evidence proving multi-component exercise intervention could make an impact on other fall-related measures even it probably could reduce the risk of falling (Fusco, 2019).

Combining balance and strength training is the most common mode of multi-component exercise intervention in preventing falls in older adults. Suzuki, Kim, Yoshida, and Ishizaki (2004)

conducted a randomized control trial on 52 elderly community-dwelling Japanese women (aged > 73) and assigned them into intervention or control groups. A 6-month fall-related intervention programme was performed by the intervention group that consisted of leg/abdominal strengthening exercise, gait/balance training, resistance training using a dumbbell and rubber band, and Tai Chi. There was no clinical significant difference between the fall rate of the intervention (14.3%) and control group (16.7%) before the 6-month training; however, the rate of falls increased to 40.9% in control group at 8-month follow-up and further rose to 54.5% at 20-month while the rate of the intervention group declined to 13.6% and remained steady during the follow-up period. In addition, Suzuki et al. (2004) observed a significant improvement in tandem walk, functional reach, and self-confidence after completing the multi-component exercise training programme.

However, it was uncertain how such findings could be generalized to the working population. Two studies have investigated the effectiveness of multi-component exercise intervention on preventing falls in older (Kawagoe et al., 2010) and middle-aged (Granacher, Wick, et al., 2011) workers. Kawagoe et al. (2010) investigated the effectiveness of limbering up exercises in order to prevent falls among older workers. An eight-month intervention programme with five times a week exercise was administered to 77 male factory workers who were 50 to 64 year-old. Limbering up exercise, as known as ‘radio taiso’, is a set of warm-up exercises well-known in Japan. Workers were encouraged to work out every day along with the music that was broadcasted on radio in the morning to refresh their body and mind. Limbering up exercise contains the components of balance, agility, and muscle strength in order to improve physical performance. Specifically, the routine included toe to heel standing (promoting ankle and joint flexibility), forward range and side-range (improving muscle strength and agility, reaction time in upper extremities), single-leg squat (enhancing muscle strength, balance and ankle flexibility) and toe touching (Whipple, 1997). In addition, the tempo is required to be maintained at 130 to 140 BPM to ensure agility and reaction time could be promoted. Guided by an instructor, the subjects had to work out five times a week before they started their work in the morning for eight months.

After the eight-month intervention, single-leg balance test with eyes closed (static balance), square step test (agility), maximum step length (flexibility) and chair standing test (muscle strength) were improved significantly (Kawagoe et al., 2010). Furthermore, their fall risks decreased significantly from 13 to 4 (16.88% to 5.19%; $p < 0.05$) in actual falls, and from 36 to 19 (46.75% to 24.68%; $p < 0.001$) in near fall experiences. Nonetheless, there were no difference in single leg balance test with eyes opened (static balance), functional reach test (dynamic balance) and timed up and go test (mobility) between measurements of pre- and post-intervention. In summary, this study showed that limbering up exercise (i.e. radio taiso) could potentially improve physical performance that correlates to risk factors of falling in occupational setting as well as reduce the rate of falls among the older working population.

Likewise, Granacher, Wick, et al. (2011) conducted an 8-week balance and strength training at worksite for 32 middle-aged (aged 50 or above) sedentary office workers, followed by 8 weeks of detraining. Similar to the study conducted by Kawagoe et al. (2010), their intervention emphasized on balance exercises and strength training. Subjects who were assigned to the intervention group exercised in their office 3 sessions per day, and 5 days per week for 8 weeks in total. The first training was required to be done in the morning before work and it included static balance exercises such as bipedal and unipedal stances. The second session was conducted after their lunch break which consisted of dynamic balance exercises, such as forward and backward tandem gait. The last training of a day was implemented in the evening before leaving their workplace and it consisted of strength exercises targeting lower extremities, such as bipedal/unipedal squats and calves raises. However, unlike the limbering exercise (Kawagoe et al., 2010), the intensity of the training programme progressed regularly by reducing the base of support (e.g. varying distance of the feet), cutting down sensory input (e.g. closing eyes) and adding extra upper body tasks (e.g. swinging arms) during the whole exercise intervention period (Granacher, Wick, et al., 2011). Moreover, subjects were required to perform exercises with bare feet or socks under static/stable surface (e.g. floor), or dynamic/unstable surface (e.g. balance beam and foam) with one leg or both legs in standing position.

After 8 weeks of training, the measuring results of postural sway during one-legged stance, gait velocity, peak isometric/isokinetic peak torque, rate of torque development of the plantar flexors and jumping height were significantly improved. Although the 8-week detraining period led to deterioration of muscle strength, performance of postural control among the middle-aged workers showed further improvement even without further training. Such results supported previous findings that increasing capacity of rapid production of lower extremity force could effectively address some intrinsic fall risk factors (e.g. reduction in postural balance and muscle strength), leading to better postural control and balance recovery, as well as reduced fall risks even in occupational setting in a long run (Granacher, Wick, et al., 2011; Suetta, Magnusson, Beyer, & Kjaer, 2007).

In summary, the systematic reviews (Goodwin et al., 2014; Sherrington et al., 2019) determined that multi-component exercise intervention could be effective in lowering the rate of falls and risk of falling with moderate certainty of evidence among community dwelling elderly people. It is not easy to evaluate the effectiveness of multi-component exercise training because of the wide variety in the use of exercise combinations and proportions of exercise elements that were incorporated in the training programme (Fusco, 2019). Yet the efficacy of fall reduction remained unclear when the comparison between multi-component exercise intervention and other single type of exercise intervention was made (Fusco, 2019). Mixed intervention (most commonly balance and strength training) achieved varied degree of success on improving physical performance that correlates to fall-risked factors, as well as the incidence of fall in community-dwelling elderly adults (Suzuki et al., 2004), older workers (Kawagoe et al., 2010), and sedentary middle-aged workers (Granacher, Wick, et al., 2011).

5.4 *Suggestions on designing a fall-preventive exercise intervention*

It is not easy to determine an ideal training programme from previous literature since the mode, intensity, volume and frequency were relatively heterogeneous (Granacher, Muehlbaue, et al., 2011). This is further complicated when multi-component balance training was involved as it was uncertain which component contributed the most to the overall improvement in balance ability. Goodwin et al. (2014) suggested combining single-component exercise together that had been proved effective would be impulsive; therefore, further studies are needed to indicate the effectiveness of multi-component exercise intervention.

Tiedemann et al. (2011) have demonstrated that the highest rate of falls reduction (up to 42%) among various exercise intervention were identified when exercise programmes exclude walking component and include challenging balance exercises on a regular basis for more than 50 hours. Instead of just focusing on the at-risk population, it is important to address the general population as well for preventive measures (Donath et al., 2016). The intervention programme should at least require a moderate level of balancing demand and should be practiced for two hours each week in a regular basis (Donath et al., 2016).

It is important to apply the latest scientific findings and modify the current balance training programme which should consist of standing exercises with (1) reducing base of support progressively, (2) involve exercise with dynamic movement that disrupt the center of gravity, and (3) contain drills that stress postural muscle group as well as adjust sensory input (Donath et al., 2016). Likewise, various exercise progressions were also advised in six features, namely: (1) surface (e.g. foam, mats, firm), (2) base of support (e.g. step stance, tandem stance and single leg stance), (3) perturbation (e.g. at the trunk, tripping), (4) loading postural muscle group (e.g. toe stance), (5) sensory input (e.g. standing with eyes closed) and (6) interference tasks (e.g. dual or triple tasks, motor and/or cognitive) (Chodzko-Zajko et al., 2009; Granacher, Muehlbauer, & Gruber, 2012; Muehlbauer, Roth, Bopp, & Granacher, 2012; Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011). Specifically, combining current gait and balance exercise with multi-task

training (i.e. with cognitive and/or motor interference tasks) to mimic real-life situations has been advocated to be included in the exercise programme to maximize their effectiveness and lasting effects in reducing falls (Dorfman et al., 2014; Granacher, Muehlbaue, et al., 2011; Granacher et al., 2012).

5.5 Conclusions

This paper described various types of exercise intervention and their corresponding effects in reducing fall-related outcome or improving balance capabilities. Effectiveness of some types of exercise intervention have been established in reducing prevalence and severity of falls among community-dwelling elderly people (Gillespie et al., 2012; Sherrington et al., 2019); however, it is important to note that most of the fall prevention findings covered in the current systematic reviews and RCTs were mainly focusing on older adults. Studies concerning the prevention of STF incidents among the working population are very limited. Though it is still possible that some of the previous findings can be applicable to the older working class, it is uncertain how the middle-aged or younger adults would respond to such interventions. Certainly, further studies are warranted to evaluate diverse exercise interventions in preventing STFs in occupational settings.

6 Designing fall prevention programme to prevent occupational slips, trips and falls on same level

Based on the recommendations from our literature review ([Chapter 5](#)), we were certain that multi-modal exercise intervention is necessary to reduce fall incidence among workers in different occupational settings Goodwin et al. (2014). Therefore, we have identified four categories of exercises that are both important and feasible to be included in our fall prevention programme in occupational settings:

1. Gait and functional balance training
2. Resistance training (with resistance band or body weight)
3. Three-dimensional (Tai Chi) exercise
4. Dual-task (motor and cognitive) training

In order to attain significant physiological changes to affect balance control, we have proposed a 12-week exercise intervention programme with progressively more challenging tasks (DiStefano, Clark, & Padua, 2009). According to Physical Stress Theory, physical stress such as exercise interventions must be applied to stimulate adaptative responses in any biological tissue (Mueller & Maluf, 2002). To minimize disruption to their usual work schedule, participants were asked to exercise twice a day (10-15 minutes per session) for five days every week to achieve the target of having at least two hours of regular training per week (Donath et al., 2016). To minimize fatigue, the morning session started off with dynamic warmup exercises followed by static balance training (i.e. standing in different stance while performing other upper body tasks), whereas the afternoon sessions alternated between dynamic balance training (i.e. walking/hopping/single leg deadlift) and resistance exercises (i.e. upper/lower body and core) aimed to improve muscle power. Tai Chi, a proven fall intervention exercise was used as cool down exercises after the afternoon session.

The difficulty of each training module (i.e. static balance, [Figure 6.1](#); dynamic balance, [Figure 6.2](#); resistance training, [Figure 6.3](#)) increased progressively every two weeks (e.g. with more challenging stance, motor/cognitive interference, disrupted sensory input, increasing intensity/magnitude, etc.) to minimize adaptation effect ([Table 6.1](#)). Participants were instructed to follow the trainers and the verbal cues given in our online exercise videos. To remind participants to perform these trainings regularly, Virtual Trainer ([Chapter 7](#)), a mobile exercise app developed by Prof. Hui, was used to prompt them to do these exercises based on their preferred schedule.

Week 1-2	Week 3-4	Week 5-6	Week 7-8	Week 9-10	Week 11-12
Dynamic Warm Up					
Feet-together Stance	Tandem Stance	Single Leg Stance	Single Leg Stance	Single Leg Stance	Single Leg Stance
+Motor Interference	+Motor Interference	+Cognitive Interference	+Motor Interference	+Motor & Cognitive Interference	+Motor & Cognitive Interference
+Eyes Closed	-Semi-Tandem +Eyes Closed	+Eyes Closed	+Eyes Closed +Calf Raise +Form a group	+Eyes Closed +Calf Raise +Form a group	+Eyes Closed +Calf Raise +Form a group
					

Figure 6.1. Static balance training (morning session)

Week 1-2	Week 3-4	Week 5-6	Week 7-8	Week 9-10	Week 11-12
Walk -High Knee -Tandem -Cross Step	Walk -High Knee -Tandem -Cross Step	Walk -Tandem -Cross Step	High Knee Walk -Tandem -Cross Step	High Knee Walk -Tandem -Cross Step	High Knee Walk -Tandem -Cross Step
Hop -Double- Leg	Hop -Single- Leg	Hop -Single- Leg	Hop -Single- Leg	Hop -Single- Leg	Hop -Single- Leg
Single Leg Deadlift	Single Leg Deadlift +Motor interference	Single Leg Deadlift +Cognitive interference	Single Leg Deadlift +Motor interference	Single Leg Deadlift +Motor & cognitive interference	Single Leg Deadlift +Motor & cognitive interference
+Eyes Closed +Head turn	+Eyes Closed +Head turn	+Eyes Closed +Head Turn +High Knee +Form a group	+Eyes Closed +Head Turn	+Eyes Closed +Head Turn +Form a group	+Eyes Closed +Head Turn
Cool down: Tai Chi					

Figure 6.2. Dynamic balance training (afternoon session – type 1)

Week 1-2	Week 3-4	Week 5-6	Week 7-8	Week 9-10	Week 11-12
Dynamic Warm Up					
Upper body -TheraBand	Upper body -TheraBand	Upper body -TheraBand	Upper body -TheraBand	Upper body -TheraBand	Upper body -TheraBand
Core	Core	Core	Core	Core	Core
Lower Body	Lower Body +Intensity	Lower Body +Intensity +Jump +distance	Lower Body +Intensity +Moving Distance +Jump +Distance	Lower Body +Intensity +Moving Distance +Jump +Distance	Lower Body +Intensity +Moving Distance +Jump +Distance
Cool down: Tai Chi					

Figure 6.3. Resistance training (afternoon session – type 2)

Table 6.1. Links to online exercise videos

	Week 1-2	Week 3-4	Week 5-6	Week 7-8	Week 9-10	Week 11-12
<i>Static balance</i>						
<i>Dynamic balance</i>						
<i>Resistance training</i>						

7 Virtual Trainer mobile app

We have modified Prof. Hui's Virtual Trainer (VT) mobile application in 2020-21 to support this OSHC project. To facilitate the setup procedure, we have pre-assigned a login ID for each participant so that they could log into their individualized account. Furthermore, we have pre-set their training schedule based on their preference or work schedule. Upon joining this study, all users were instructed to download and install the Virtual Trainer mobile app onto their phones through Google Play for devices running Android, or App Store for Apple iPhones, by searching “VTHK”.

After logging into their account, they could access their “Fitness Log” by pressing the top left icon (*Figure 7.1*).



Figure 7.1. Virtual Trainer (VT) mobile application login screen (left) and fitness log (right)

Inside the fitness log, users could modify the settings (*Figure 7.2*) such that the mobile app would send them notifications to prompt them to perform the assigned exercise at their preferred timeslots, and to remind them to complete the reply form after each training session.



Figure 7.2. Virtual Trainer (VT) mobile application Fitness log settings – Turning on notifications

Within the fitness log, users could view their daily exercise prescriptions, as well as all incomplete reply forms. Users could simply enter the actual exercise time duration and self-perceived exercise intensity to complete each reply form (*Figure 7.3*).

Figure 7.3. Virtual Trainer (VT) mobile application Fitness log – Completing the reply form

In summary, the Virtual Trainer mobile app was a convenient tool that could prompt users to perform the prescribed exercises at their preferred timeslots automatically. Users could easily view and modify their own exercise plan to fit their own schedule. Users could also view the exercise videos through the mobile app so that they would know exactly what to do for each exercise session. For more details, please refer to *Appendix A: Using Virtual Trainer*.

8 Pilot study to test the feasibility of our fall prevention programme

8.1 Overview

The objectives of this pilot study were to: (1) examine the feasibility of our exercise interventions and assessment protocol, and (2) collect pilot data to estimate the total number of participants needed to establish the effectiveness of our exercise interventions.

8.2 Methods

8.2.1 Participants

Twenty-one healthy adults (8 males and 13 females; height = 163.8 ± 11.6 cm; weight = 66.4 ± 12.3 kg) working in catering and accommodation industries were included in this pilot study after they have given written consent. They were all non-fallers aged 22 to 61 (mean = 42.5 ± 11.8 yr). The study protocol was compliant with the Declaration of Helsinki and International Conference on Harmonisation – Good clinical practice (ICH-GCP), and was approved by the Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee (Joint CUHK-NTEC CREC).

8.2.2 Training protocol

As detailed in [Chapter 7](#), we have proposed a 12-week exercise intervention programme in which workers were asked to exercise twice a day for five days every week. Every training session would last around 10-15 minutes to minimize disruption to their usual work schedule and living habits. To minimize fatigue, the morning session would start off with dynamic warmup exercises followed by static balance training (i.e. standing in a different stance while performing other upper body tasks), whereas the afternoon/evening session would alternate between dynamic balance

training (i.e. walking/hopping/single leg deadlift) and resistance exercises (i.e. upper/lower body and core) aimed to improve muscle power. Tai Chi, a proven fall intervention exercise was used as a cooldown exercise after the afternoon/evening session (Li et al., 2005).

The difficulty of each training module would increase progressively (e.g. with more challenging stance, motor/cognitive interference, disrupted sensory input, increasing intensity/magnitude, etc.) to minimize the adaptation effect. Furthermore, exercise videos were posted online for workers to follow during their training sessions. To remind participants to perform these trainings, Virtual Trainer (www.vt.hk), a mobile exercise app developed by Prof. Hui, was used to prompt them to do these exercises based on their preferred schedule (*Chapter 7*). Subjects were encouraged to record their completed training sessions using the mobile app for us to verify their compliance. However, due to some technical issues, the Virtual Trainer App was not launched until around 6-weeks into the commencement of the pilot study. WhatsApp was used instead to prompt and remind participants to engage in the exercise intervention in the first six weeks.

8.2.3 Assessments

Pre- and post-training assessments were conducted to quantify each individual's physical performance and fall risk. Specifically, fall risk was estimated using a shortened version of the JISHA (Japan Industrial Safety and Health Association) questionnaire (i.e. Q1, 5, 11, 12, 18, and 25). The simplified version was used because it has been found that these six items would yield similar area under the receiver operating characteristic (ROC) curve as the original JISHA occupational slip, trip and fall risk assessment test (Nakamura et al., 2016), suggesting the shortened version had the same predictive power as the full version. Physical performance was evaluated using a few simple tests, i.e. (1) Static balance: *Single-leg balance test with eyes closed* (longer time was better), (2) Dynamic balance: *Functional reach test* (longer displacement, normalized to body height, was better) and *Y-balance test* (longer total displacement in three directions, i.e. anterior, medioposterior and lateroposterior, normalized to body height, was better),

(3) Agility: *Four-square step test* (shorter time was better), and (4) Muscle strength: *Five Chair Sit to Stand Test* (shorter time was better). Since our participants came from the working population instead of the frailer and older group, these tests were chosen over the common fall risk screening tools (e.g. Berg Balance Scale, Tinetti Test, Mini-BESTest) to avoid ceiling effect. For details, please see [Figure 8. 1](#).

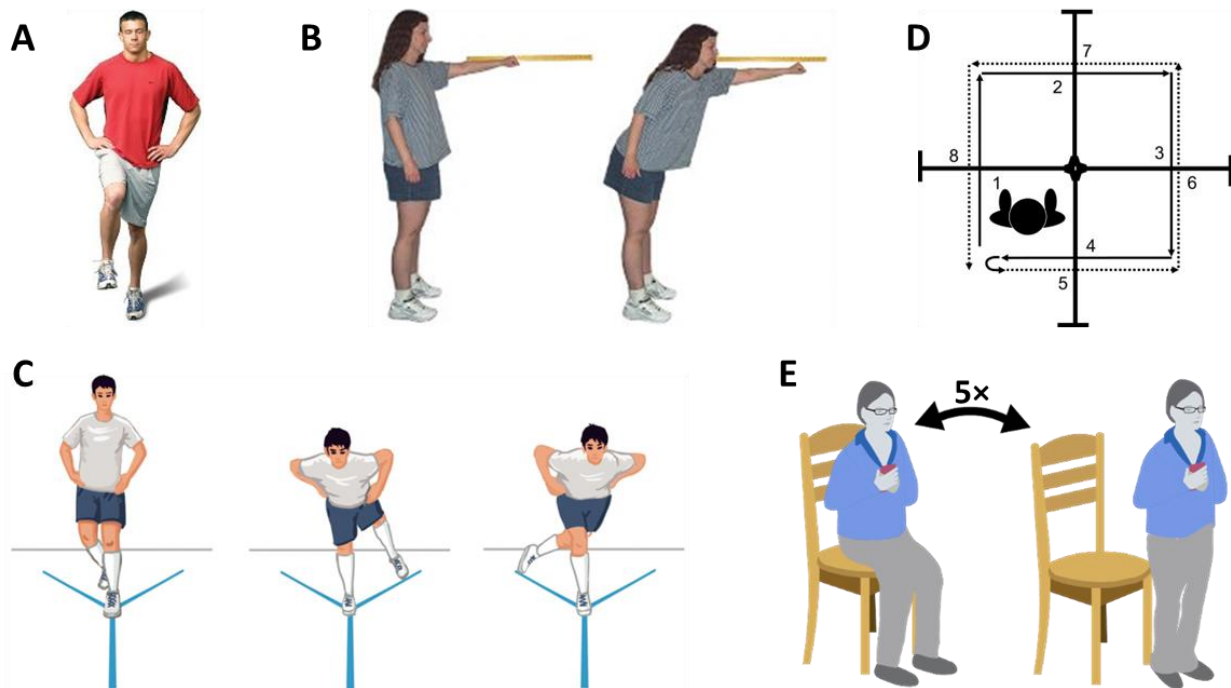


Figure 8.1. Clinical assessments. Five clinical tests were used to measure: (1) static balance with (A) Single leg stance test with eyes closed; (2) dynamic balance with (B) Functional reach test and (C) Y-balance test; (3) agility with (D) Four-squares step test, and (4) leg power with (E) Five-time sit-to-stand test. For further details, please refer to: <https://www.sralab.org/rehabilitation-measures/>.

8.2.4 Statistical analyses

Paired sample t-test, or Wilcoxon signed-rank test if the data were not normally distributed, was used to evaluate the effectiveness of our exercise intervention. Pearson's correlation was used to verify whether age and gender had any modulating effect on their performances. Statistical analyses was performed by SPSS 27.0. The criterion level of significance for all analyses was 0.05.

8.3 Preliminary results

Despite the relatively small sample size, preliminary results from 21 non-fallers from catering and accommodation industries revealed that our exercise intervention was effective in improving balance control among these young to middle-aged workers. The means and standard deviations of pre- and post-intervention scores of all assessments were summarized in [Table 8.1](#). Although there was no significant improvement in their functional reach displacement and JISHA questionnaire score, our participants were able to improve their static balance control, dynamic balance control, agility, and leg muscle power (P 's<0.05). Nevertheless, there was no evidence that gender ($r^2=0.01-0.411$, p 's>0.064) and age ($r^2=0.00-0.113$, p 's>0.136) had any statistically significant effect on any of our outcome measures.

Table 8.1. Pilot results of our 12-week progressive, multi-modal fall prevention exercise intervention programme

	Pre	Post	p-value
Fall risk			
• JISHA STF risk assessment test (simplified) (total score)	1.48±0.98	1.24±0.44	p=0.135
Static balance			
• Single-leg balance test with eyes closed, dominant leg (seconds)	11.7±16.0	21.0±27.6	p=0.007 **
• Single-leg balance test with eyes closed, non-dominant leg (seconds)	11.7±14.4	19.1±24.6	p=0.022 *
Dynamic balance			
• Functional reach test (%body height)	17.9±4.1	18.6±3.1	p=0.291
• Y-balance test, dominant leg (body height)	1.20±0.21	1.47±0.21	p<0.001 ***
• Y-balance test, non-dominant leg (body height)	1.21±0.21	1.47±0.24	p<0.001 ***
Agility			
• Four-square step test (seconds)	6.92±1.59	5.57±1.13	p<0.001 ***
Leg muscle strength and power			
• Five-time sit-to-stand test (seconds)	8.33±2.42	5.99±1.19	p<0.001 ***

Note: values are presented as mean ± standard deviation; the level of statistical significance was set at 0.05; * <0.05, **<0.01, ***<0.001.

8.4 Preliminary discussions

To our knowledge, this is one of the first studies to investigate the effectiveness of a multi-modal fall prevention exercise intervention aimed to reduce fall risks among healthy adults in occupational settings. All participants were able to complete the 12-weeks exercise interventions with no ill effects. Our pilot study showed that our fall prevention programme was feasible and effective in improving workers' balance control who have no previous fall history. Furthermore, we have demonstrated that our assessment methods were suitable in quantifying improvement among this population, as there was no ceiling effect even for healthy adults and was sensitive in detecting changes in their balance ability. Although there was no improvement in their JISHA score, this was expected as some questions were about their living and working environment/nature.

Although we were confident that our exercise interventions would be effective in improving balance control among healthy adults, it was still surprising to obtain such overwhelming improvement with our non-faller participants, despite the small sample size. We expect similar or greater improvement among fallers as they have a greater capacity for improvement relative to non-fallers. With the newly acquired pilot data (effect sizes > 0.6), it was estimated using G*Power ($\alpha=0.05$ and power=0.80) that we would only need to recruit a minimum of 76 subjects to establish the effectiveness of our fall prevention programme. To be more conservative, we are proposing to recruit 100 participants for the main cohort study. In order to have greater generalizability, more workers from the construction industry are needed as these people come from one of the most physically-demanding working environment and may respond more differently to our training protocol.

8.5 *Conclusions*

This pilot study had successfully demonstrated both the feasibility and effectiveness of our fall prevention programme in an occupational setting. We were looking forward to recruiting more participants from the construction industry to complete the main cohort study. We were confident that with a larger sample size and a more diversified sample population, we would be able to establish the effectiveness of our exercise interventions. Ultimately, we would like to promote this intervention to workers in different occupational settings to reduce their fall risk and incidence.

9 Cohort study to evaluate the effectiveness of our fall prevention programme

9.1 Overview

In this study, we aimed to investigate the effectiveness of our 12-week progressive, multi-modal fall prevention exercise programme with online video demonstration and reminder in occupational settings. We hypothesized that workers would have significantly improved balance control after the 12-week exercise training period. We also explored whether workers from the catering and construction industries would be benefited differently with our exercise intervention.

9.2 Methods

9.2.1 Participants

Workers from different industries were recruited to participate in this study. Due to their higher fall incidence rate, workers in the construction and catering industries were prioritized, though workers in other industries were also welcomed. All participants provided written informed consent prior to taking part in the experiment. All procedures were performed in accordance with the Declaration of Helsinki and was approved by the Joint Chinese University of Hong Kong - New Territories East Cluster Clinical Research Ethics Committee.

9.2.2 Training protocol

To minimize interference by peers in different groups, they were cluster-randomized into the experimental and control group. The experimental group would perform 12 weeks of progressive, multi-modal exercise intervention, whereas the control group would perform 12 weeks of stretching exercises that should have minimal effectiveness in improving balance control. The total amount of exercise training was similar between the two groups. Each participant was

prompted by a mobile app (Virtual Trainer, see [Chapter 7](#)) to perform 10-15 minutes of exercises twice a day in their preferred timeslots for five days a week. As discussed in [Chapter 6](#), the experimental group was asked to perform static balance training in the first session of the day (i.e. usually before work), and dynamic balance training or resistance training in the second session of the day (i.e. usually during their break time or after work). The difficulty and intensity of each training module (i.e. static balance, dynamic balance, and resistance training) would progressively increase every two weeks to maximize physiological adaptation to the increasing stress to the musculoskeletal and sensory systems.

9.2.3 Assessments

All participants were evaluated twice (i.e. before and after the exercise intervention) by our trained research staffs. Besides using the simplified STF risk assessment test (Japan Industrial Safety and Health Association, 2010) developed by the Japan Industrial Safety and Health Association (JISHA) to determine individual's fall risk in occupational settings ([Table 9.1](#)), same as the pilot study ([Chapter 8](#)), five additional physical assessments were also used:

1. Static balance control
 - *Single-leg balance test with eyes closed*: longer stance time is better
2. Dynamic balance control
 - *Functional reach test*: further arm reaching distance is better
 - *Y-balance test*: further leg reaching distance is better
3. Agility
 - *Four-square step test*: faster task completion time is better
4. Muscle strength and power
 - *Five-time sit-to-stand test*: faster task completion time is better

The abovementioned tests ([Figure 8.1](#)) were chosen instead of the more commonly used Berg Balance Scale (BBS), Tinetti Mobility Score (TMS) and Mini Balance Evaluation Systems Test

(Mini BESTest) was because those assessments were designed mainly for older adults or rehabilitation settings. These tests have showed significant ceiling effect for those in occupational settings.

9.2.4 Statistical Analyses

Using age and gender as covariates, two-way repeated measure ANCOVA were used to determine the main and interaction effects of time (i.e. pre vs. post) and group (i.e. experimental vs. control). Ranked transformed ANCOVA would be used instead as the non-parametric alternative if any of the assumptions for ANCOVA test were violated. Paired sample t-test, or Wilcoxon signed-rank test if the data were not normally distributed, was used to confirm changes within the experimental and control groups in the post-hoc analyses. In addition, the same analyses with the same covariates were used to determine the main and interaction effects of time (i.e. pre vs. post) and industry (i.e. catering vs. construction) among the experimental group. Statistical analyses was performed by SPSS 27.0. The level of statistical significance was set at 0.05.

Table 9.1. Simplified JISHA fall risk questionnaire.

Q1	人ごみの中、正面から来る人にぶつからず、よけて歩けますか Can you walk without bumping into a person in a crowd? 你能在人群中行走而不撞到迎面而來的人嗎？
Q5	片足で立ったまま靴下を履くことができますか Can you put on your socks while standing on one leg? 你能夠單腳站立時穿襪子嗎？
Q11	自宅で、バリアフリー化、手すりの設置、床や階段の滑り止めなどの対策をとっていますか Have you taken fall prevention measures such as construction of barrier-free environments or railings at home? 你有否在家中採取預防跌倒的措施嗎？例如建造無障礙環境或安裝扶手。
Q12	仕事をしている最中に走ることはありますか Do you run while at work? 你在工作時有跑動嗎？
Q18	ここ1年間で、仕事中に転んだことがありますか Have you fallen at work in the past year? 在過去一年中，你曾經在工作時跌倒嗎？
Q25	相手の話を聞きながら返答を考えることができますか Can you think of an answer to a person's question while listening to him or her talk? 你能在別人跟你說話時想到回應嗎？

9.3 Results

A total of 105 workers from construction, catering, transportation and security industries were recruited to participate in this study. Of which, 12 participants dropped-out from the study due to COVID-related reasons, emigration, career changes, and busy work schedules. Hence, the final data analyses included N=93 participants, with 41 in the experimental group and 52 in the control group ([Table 9.2](#)). Statistical tests showed there was no difference in the demographics and baseline values between the two groups.

Table 9.2. Participants' demographics.

	Experimental	Control
N	41	52
Age (yr)	37.73 ± 10.60	43.87 ± 13.39
Gender	25 M / 16 F	27 M / 25 F
Height (cm)	167.73 ± 10.27	164.88 ± 10.55
Weight (kg)	68.87 ± 13.48	63.97 ± 12.48
Occupation	Catering: 21 Construction: 20 Others: 0	Catering: 12 Construction: 32 Others: 8*

* Others: Transportation (2), Manufacturing (2), Security (3), Social work (1)

9.3.1 Experimental vs. control group

Taken into accounts effects of the covariates such as age and gender, significant time $\times$ group interactions revealed the experimental group had greater improvement in their static balance control (i.e. Single-leg balance test with eyes closed; p 's=0.008-0.022), dynamic balance control (i.e. Y-balance test; p 's<0.001), agility (i.e. Four-square step test; p <0.001), and leg muscle strength and power (i.e. Five-time sit-to-stand test; p <0.001) in comparison to the control group. Post-hoc analyses revealed significant improvement of the experimental groups in all of the abovementioned assessments (p 's $\leq$ 0.001-0.010). However, no significant main effect nor interaction was found for the JISHA questionnaire and Functional reach test assessments. Please refer to [Table 9.3](#) for summary of results.

Table 9.3. Effects of our 12-week progressive, multi-modal fall prevention exercise intervention programme

	Experimental		Control		Interaction
	Pre	Post	Pre	Post	p-value
Fall risk					
• JISHA STF risk assessment test (simplified) (total score)	1.46 $\pm$ 0.84	1.37 $\pm$ 0.58 p =0.378	1.37 $\pm$ 0.84	1.44 $\pm$ 0.77 p =0.399	p =0.135
Static balance					
• Single-leg balance test with eyes closed, dominant leg (seconds)	15.8 $\pm$ 22.3	25.9 $\pm$ 30.6 p <0.001 ***	17.0 $\pm$ 16.4	17.8 $\pm$ 16.3 p =0.692	p =0.008 **
• Single-leg balance test with eyes closed, non-dominant leg (seconds)	15.7 $\pm$ 20.7	28.6 $\pm$ 43.5 p =0.011 *	15.5 $\pm$ 17.0	15.6 $\pm$ 15.1 p =0.937	p =0.022 *
Dynamic balance					
• Functional reach test (% body height)	19.1 $\pm$ 4.0	19.8 $\pm$ 3.6 p =0.196	19.4 $\pm$ 4.1	19.5 $\pm$ 3.2 p =0.756	p =0.387
• Y-balance test, dominant leg (body height)	1.24 $\pm$ 0.18	1.43 $\pm$ 0.18 p <0.001 ***	1.23 $\pm$ 0.17	1.26 $\pm$ 0.17 p =0.010 *	p <0.001 ***
• Y-balance test, non-dominant leg (body height)	1.25 $\pm$ 0.18	1.43 $\pm$ 0.20 p <0.001 ***	1.24 $\pm$ 0.17	1.26 $\pm$ 0.17 p =0.065	p <0.001 ***
Agility					
• Four-square step test (seconds)	6.83 $\pm$ 1.46	5.82 $\pm$ 1.28 p <0.001 ***	7.16 $\pm$ 2.09	7.31 $\pm$ 1.63 p =0.399	p <0.001 ***
Leg muscle strength and power					
• Five-time sit-to-stand test (seconds)	7.44 $\pm$ 2.30	6.12 $\pm$ 1.40 p <0.001 ***	7.43 $\pm$ 1.86	7.26 $\pm$ 1.68 p =0.251	p <0.001 ***

Note: values are presented as mean $\pm$ standard deviation; p-values presented below and pre- and post-means were results from post-hoc analyses of within group differences; the level of statistical significance was set at 0.05; * <0.05, **<0.01, ***<0.001.

9.3.2 *Catering vs. construction industry*

Similarly, significant time $\times$ industry interactions were observed for dynamic balance control (i.e. Star exercise balance test; $p's \leq 0.001-0.002$), agility (i.e. Four-square step test; $p=0.050$), and leg muscle strength and power (i.e. Five-time sit-to-stand test; $p=0.004$) after considering effects of age and gender, revealing the amount of improvement for these tests were different between the two industries. Post-hoc analyses showed that both the catering and construction groups had significantly improved performance on their Y-balance test ($p's < 0.001$), though the catering group had even greater improvement than the construction workers with both their dominant and non-dominant legs ($p's \leq 0.001-0.002$). Similarly, the catering group ($p < 0.001$) had greater improvement in their agility (i.e. Four-squares step test) than the construction workers ($p=0.003$). Unsurprisingly, unlike the catering group who became significantly stronger with their lower extremity muscles ($p < 0.001$), construction workers did not have significantly improved leg muscle strength and power ($p=0.372$) after the intervention. The lack of significant interaction for the Single-leg balance tests suggested workers from either industry had similar improvement in their static balance control. Post-hoc analyses with Wilcoxon signed-rank test revealed workers in both the catering and construction industries improved their static balance of their dominant (catering: $p=0.002$; construction: $p=0.002$) and non-dominant (catering: $p=0.017$; construction: $p=0.028$) legs. Please refer to [Table 9.4](#) for summary of results.

Table 9.4. Effects of our 12-week progressive, multi-modal fall prevention exercise intervention programme on catering vs. construction industry

	Catering Pre	Catering Post	Construction Pre	Construction Post	Interaction p-value
Fall risk					
• JISHA STF risk assessment test (simplified) (total score)	1.48±0.98	1.24±0.44 p=0.261	1.45±0.69	1.50±0.69 p=0.330	p=0.973
Static balance					
• Single-leg balance test with eyes closed, dominant leg (seconds)	11.2±16.1	20.9±27.6 p=0.002 **	20.5±27.0	31.1±30.6 p=0.002 **	p=0.941
• Single-leg balance test with eyes closed, non-dominant leg (seconds)	12.2±14.4	19.2±24.5 p=0.017 *	19.3±25.7	38.5±56.1 p=0.028 **	p=0.212
Dynamic balance					
• Functional reach test (% body height)	17.9±4.1	18.6±3.1 p=0.291	20.3±3.5	20.9±3.8 p=0.459	p=0.358
• Y-balance test, dominant leg (body height)	1.20 ±0.21	1.47 ±0.21 p<0.001***	1.29 ±0.14	1.37 ±0.14 p<0.001 * **	p<0.001 ***
• Y-balance test, non-dominant leg (body height)	1.21 ±0.21	1.47 ±0.24 p<0.001***	1.29 ±0.13	1.38 ±0.12 p<0.001 ***	p=0.002 **
Agility					
• Four-square step test (seconds)	6.92±1.59	5.57±1.13 p<0.001 ***	6.73±1.36	6.08±1.41 p=0.003 **	p=0.050 *
Leg muscle strength and power					
• Five-time sit-to-stand test (seconds)	8.33±2.42	5.99±1.19 p<0.001 ***	6.50±1.79	6.27±1.62 p=0.372	p=0.004 **

Note: values are presented as mean ± standard deviation; p-values presented below and pre- and post-means were results from post-hoc analyses of within industry differences; the level of statistical significance was set at 0.05; * <0.05, **<0.01, ***<0.001.

9.4 Discussions

As hypothesized, experimental group who underwent 12 weeks of progressive, multi-modal balance training had significantly improved balance control in multiple domains (i.e. static balance, dynamic balance, agility, and leg muscle strength and power) in comparison to the control group, regardless of their age and gender. Even construction workers have showed significant improvement in their agility, as well as enhanced static and dynamic balance control. These results suggested that our intervention programme is suitable for those who are physically active, either due to job nature or living habit, as strong musculature is not the only factor needed for good balance control. Our findings also showed that people working in the catering industry tended to have greater improvement than construction workers except for static balance, as both groups had improved similarly in that regard. This suggested our 12-week balance training should provide even greater benefits for more sedentary or less physically active individuals, such as those who mainly sit in front of a desk.

Despite only including 93 participants in our final analyses, we have covered a wide range of age group (21-74yr), across both genders (52 male and 41 female), and two industries with the highest fall incidence rate (construction: 52, catering: 33; [Table 9.2](#)). Besides the JISHA and functional reach test, our participants in the experimental group had an overwhelmingly significant improvement in all four aspect of balance and mobility ([Table 9.3](#)). For static balance, our experimental group was able to stand on one leg with their eyes closed for 64.4-82.5% longer than before they had the training (control: 0.9-5.0% improvement). For dynamic balance, they could reach with one of their legs in three different directions 14.2-14.7% further after the intervention (control: 2.0-3.0% improvement). Our experimental group was also more agile in their Four-square step tests (experimental: +14.7% vs. control: -2.1%) and had markedly stronger leg musculature resulting in faster completion time for the Five-time sit-to-stand test (experimental: +17.7% vs. control: +2.3%). It was very encouraging to see this intervention was so effective in improving multiple aspect of balance and mobility among a wide range of workers from different age group and industries in just 12 short weeks. Traditionally it was believed only older adults with balance impairment would require fall prevention programme; however, the results from this study demonstrated that even workers in physically demanding industries such as construction and catering could be benefited by a carefully designed, progressive, multi-modal balance training programme.

The lack of improvement of leg muscle strength and power among the construction workers was expected as these individuals tended to have stronger leg muscles prior to joining this programme ([Table 9.4](#)), and have less capacity for improvement. They will need to use higher resistances during the resistance-training module in order to provide sufficient mechanical stimulation to trigger more significant muscle hypertrophy in their legs; however, this should not be necessary as they generally do not lack sufficient muscle strength and power to perform effective compensatory balance-recovery reactions to prevent falls when they experience balance perturbations. Finally, the lack of improvement in the JISHA STF risk assessment test was unsurprising as some of those questions were related to their home and work environment instead of their balance control. Furthermore, as almost all of our participants were healthy individuals without obvious balance impairment and occupational fall history prior to joining our study, it was

expected that they would remain as low risk fallers as identified by the JISHA STF risk assessment test after the intervention. Similarly, the lack of improvement in their functional reach distance could be attributed to our training focused more on their balance control instead of general flexibility, which would also be needed to have significant improvement in their reaching displacement. Moreover, occasionally the assessment venues provided by the participating units were less than ideal and imposed great difficulty for our research staff to take accurate measurement of the workers' functional reach distance (i.e. lack of a suitable wall to tape our measuring tool on). Nevertheless, with the overwhelmingly significant improvement in all other clinical assessments covering static balance control, dynamic balance control, agility and leg power, our 12-week fall prevention programme can definitely help workers from different industries to lower their fall risk.

By breaking down the two hours of weekly balance training (Donath et al., 2016) into ten short sessions of 10-15min intervals (i.e. 2 sessions per day, 5 days a week), workers from different industries should find it easier to incorporate our overwhelmingly effective fall prevention programme into their daily routine, as evident by the high adherence to our intervention programme among the experimental group. This practice should be strongly encouraged especially for industries that have reported the highest fall incidence rate, i.e. construction, catering, manufacturing and security industries. The fact that no adverse event has been reported showed our programme is both safe and feasible for workers of different ages and gender across various industries. Although our results showed that our intervention was effective regardless of the participants' age and gender, older workers with slower reflexes and higher fall risk are in more desperate need to enhance their balance and gait control to prevent occupational slips, trips and falls that can lead to severe physical and economic consequences. Upon the completion of the 12-week fall intervention programme, participants can choose to continue to train with our protocol at the highest difficulty level to maintain or further improve their balance control. Alternatively, they may choose to at least repeat our 12-week fall prevention programme annually to minimize age-related decline in their balance control.

During the study period, we noticed that support from the management was an important factor in the participation of the workers. Without managerial support, workers would need to find time in their off-hours to complete the two sessions of exercise training. This was not always possible for workers with long working hour and strenuous work, as they would be too exhausted to engage in additional physical activities after work. Therefore, to fully maximize the effectiveness of our intervention, management should be advised to allocate timeslots to their employees to perform injury- and fall-preventive exercises (e.g. before the start of work and after the lunch/dinner break). This is a common practice among construction workers in our study as they often have around 10-15-minute warmup session where they perform “Eight Brocades” (Daduanjin) in the morning before they start working in their construction sites. As a result, it was relatively easier for these participants to allocate exercise time to perform our intervention. This should become a common practice among workers from various high injury- and fall-risk sectors to minimize occupational incidence.

9.4.1 *Limitations*

It should be noted that one limitation of this study was that we were unable to recruit many participants with previous fall history or have significant balance impairment. Nevertheless, our study has shown that even non-fallers could have tremendous improvement in their balance control after their 12-week training, there was little doubt that fallers with balance impairment would gain even greater benefits in lowering their fall risk. Another limitation of this study was that we did not look at the effect of training intensity on the overall effectiveness of our training programme. Nevertheless, based on other studies, overall training volume (i.e. total number of training sessions) should be more important than training frequency (i.e. how often are the training sessions) alone (Grgic et al., 2018), though individuals should maintain a regular training habit. Therefore, it should be acceptable if workers needed more than 12 weeks to complete the whole intervention (i.e. 60 sessions of static balance training, 30 sessions of dynamic balance training, and 30 sessions of resistance training) if they could not exercise as frequently as our original recommendation. Future studies would be needed to determine the optimal dose-response relationship for this

population, as well as different combinations of exercise module (e.g. static:dynamic:resistance = 60:30:30 vs. 30:60:30, 30:30:60, 60:60:0, etc.).

9.5 *Conclusions*

Our 12-week progressive, multi-modal fall prevention exercise intervention programme with online video demonstration and reminder was effective in improving balance and mobility of workers from high fall risk industries such as construction and catering. Early evidence suggested that our intervention could be more effective for those who are physically inactive as they have higher capacity for improvement. The Council should highly consider promoting this fall prevention programme to all industries that have reported high fall incidence rate (i.e. construction, catering, manufacturing and security industries). Future study is required to investigate how these functional improvements will translate to reduced incidence of slips, trips and falls on same level in occupational settings, as well as the retention effect of our fall prevention programme.

10 Focus group interview

Interviews with industry representatives were conducted after the completion of the cohort study to collect opinions on occupational slip, trip and fall accidents among the construction and catering industries, as well as potential strategies to promote our exercise programme to workers in the future. Due to the COVID-19 pandemic, these interviews were conducted over the phone instead of in-person.

10.1 Interviewees

We have interviewed representatives from both the catering industries [Eating Establishment Employees General Union (EEEGU), and Association of Restaurant Managers (ARM)] and construction industries [Hong Kong Construction Industry Employees General Union (HKCIEGU), and Hong Kong General Building Contractors Association (GBCA)].

10.2 Impact and causes of occupational slip, trip and fall

Both Employees General Union representatives identified occupational slip, trip and fall as one of the most prevalent and serious problem among their industries due to the aging working population and shortage of manpower. Due to shortage of manpower, urgency of task might potentially lead to increased walking speed and hasty behaviors, which would limit their ability to assess environmental hazards and increase their risk of fall. Specifically, workers in the catering industries were often forced to deal with a number of environmental hazards such as limited space, obstructed field of view, as well as wet and slippery surfaces. Furthermore, the lack of experienced workers in the catering industry further exacerbated the problem as newer workers often lacked sufficient safety awareness to avoid or minimize occupational fall hazards by maintaining a tidy and organized workplace. Similarly, workers in the construction industry also have to deal with untidy construction worksites, which could be challenging to their aging workforce as older workers often had weaker muscles and slower reflexes.

Representative from the Association of Restaurant Managers shared all the opinions of the employees in the catering industry. In addition, they pointed out that it was difficult to hire experienced workers in managerial roles, and these supervisors could help to ensure their workspaces were tidy and clean to minimize fall hazards. On the other hand, the building contractors do not view occupational slip, trip and fall as a prevalent and serious problem for their workers. Nevertheless, they have identified similar risk factors as the workers: i.e. site tidiness, workers' experience, safety awareness, use of personal protective equipment (PPE), etc. Furthermore, although they were aware of the aging working population among the construction industry, they felt that age-associated degeneration of muscle only affected their productivity and did not necessarily lead to increase in occupational accident rate.

10.3 Current practices to lower fall risk

Currently, workers in both industries were encouraged to use personal protective equipment (PPE) to lower their risk of fall and risk of injury. Anti-slip flooring materials were commonly used by the catering industry and workers were all encouraged to wear anti-slip shoes. Safety briefings and morning warmup exercises ("Eight Brocades" or Baduanjin) were some safety measures among the construction industry, though they were only enforced in public project sites undertaken by various government departments. Workers conducting private jobs often neglect these practices.

10.4 Strategy in promoting our exercise intervention in occupational settings

There were mixed opinions on whether workers would be interested in enrolling in our fall prevention exercise interventions. Although all interviewees agreed that fall prevention was extremely important, especially for their aging workers, some of them felt that workers would be too tired and not interested in performing exercise training in their leisure time due to their long working hours and strenuous work natures. Nevertheless, all parties involved would like to help

in the promotion of our fall prevention programme to their members. They felt that WhatsApp and YouTube could be used to share exercise videos to their workers as to raise safety awareness and motivate workers to perform our fall prevention exercises. Both Employees General Unions were willing to promote our interventions to their members through their workshops and other events. Therefore, safety managers at construction sites could be trained to use our fall prevention exercises as their morning warmup routine instead of “Eight Brocades.” They believed that changing workers’ mentality would be vital as workers would be self-motivated to perform exercise trainings once they were aware of the effectiveness of our training programme. The interviewees also stressed the importance of the flexibility of the intervention exercises, as workers in both the construction and catering industries have long and sometimes irregular working hours.

10.5 Conclusions

Most of the opinions collected through these interviews matched the findings through our literature reviews. Due to an aging working population, there was an imminent need for an effective fall prevention programme to reduce slip, trip and fall accidents in occupational settings. Currently, most of the fall prevention strategies focused mainly on the environmental issues. Though these safety practices are extremely important in reducing workplace fall hazards, it is equally important to place greater emphasis on empowering the individuals so that they will be equipped to deal with the unexpected events that will cause them to lose their balance. With an aging working population, many workers will inevitably have age-related weakening of their muscle strength and power, as well as age-related deterioration of their neuromuscular control of their balance and gait. Therefore, we have to educate them through various means to raise their awareness to enroll in our exercise intervention to lower their fall risk. This could be done through the Occupational Safety and Health Council, the government, the Employees General Unions, and other Associations. Workshops and seminars could be held to educate workers or future workers on the importance of preventing occupational slip, trip and falls. In addition, by designing our fall prevention programme using short bouts of 10-15 minutes exercises, it would be more flexible to suit the busy working schedules of the individuals.

11 Conclusions

Despite the tremendous challenges brought forth by unprecedented events (i.e. mass social protests from June 2019 to January 2020 and the global COVID-19 pandemic since early 2020) that have caused prolonged closure of the university and major disrupted work environment, thanks to the support and patience of the Occupational Safety and Health Council (OSHC), our team has managed to achieve most of the goals of this project. We have conducted thorough reviews on the status quo and risk factors of occupational slips, trips and falls on the same level (STF), as well as on the different types of exercise interventions in the report (i.e. [Chapters 3, 4 and 5](#)).

Occupational slip, trip and fall is the most common occupational incidents in Hong Kong (around 30% of all types of occupational incidents). Each year, around 25-30 workers per 10,000 workers would be injured due to slip, trip or fall. Manufacturing, construction and catering industries have reported the highest incidence rate. In comparison to other populations, Hong Kong has reported relatively higher non-fatal occupational fall incidence rate over the past decade. With an aging working population, it was expected that incident rate, severity, and financial burden of occupational slip, trip and fall would rise in the foreseeable future.

Previous studies have identified many risk factors associated with occupational falls, and these factors could be classified into environmental/extrinsic factors, human/intrinsic factors, work-related factors, and management factors. Based on our focus group interviews, it appeared that extrinsic factors such as uneven or slippery surfaces, clustered environment, etc. were key reasons of many fall incidences in Hong Kong. In addition, shortage of manpower leading to faster work pace, inexperienced workers having less safety awareness were hired, as well as lack of experienced supervisors to maintain workplace safety, also contributed to the problem. Finally, all interviewees acknowledged that aging workforce is common across different industries and age-related neuromuscular changes would affect their abilities to maintain and restore balance when being perturbed.

Traditionally, most of the research efforts have been spent on reducing fall risk among older adults (i.e. over 65 years). Few studies have investigated means to improve balance control among the working population. Nevertheless, with an aging population, the boundary dividing the working population and older population have blurred. Some of the findings from the aging studies may become applicable to occupational settings. Previous studies have shown that multi-modal exercise interventions were more effective than single-modal programme in reducing fall risk and fall incidence. Based on our review, it was found that (1) gait, balance and functional training, (2) resistance, (3) three-dimensional (e.g. Tai Chi) exercise, and (4) dual-task training were the most important elements to be incorporated into an effective fall prevention programme. Therefore, a multi-modal exercise intervention was developed by our team of experts aiming to improve the static and dynamic balance control of workers from different industries.

Our 12 weeks training programme comprised of (1) gait and functional balance training, (2) resistance training, (3) three-dimensional (e.g. Tai Chi) exercise, and (4) dual-task training, and workers were asked to exercise twice a day (around 10-15min per session) for five days every week. Dual-task paradigm was incorporated into our programme to induce neuroplasticity in the brain. Moreover, to minimize adaptation effect, the training tasks become progressively more challenging every two weeks. An online application was used to remind participants to exercise according to their own preferred schedule. After demonstrating the feasibility of our exercise intervention in our pilot study, we have conducted a cohort study with 93 workers to investigate the effectiveness of our 12 weeks, progressive, multi-modal fall prevention programme. Results showed participants from different industries have significantly improved multiple domains of their balance control (i.e. leg muscle strength and power, agility, as well as static and dynamic balance control). This was especially encouraging as almost all of our participants were healthy individuals with no balance impairment and fall history. Therefore, older workers with deteriorated balance and gait control would gain even greater benefits than those demonstrated in our cohort study. From our focus group interview, we have learned that the current safety practices placed greater emphasis on reducing environmental hazards. Therefore, our study filled an

important gap to empower individuals to help them to maintain balance and be more prepared when dealing with unexpected events that may cause them to lose their balance. Based on our findings in this consultancy study, we have provided a list of recommendations for the Councils to alleviate the high and increasing incidence of occupational slips, trips, and falls on same level in Hong Kong ([Chapter 12](#)).

12 Recommendations

After proving the effectiveness of our 12-week progressive, multi-modal fall prevention exercise intervention programme with online video demonstration and reminder in improving workers' balance and mobility control in occupational settings, it is important for the Council to translate our knowledge to the public to maximize the number of beneficiaries and lower the fall risk and fall incidence of workers in Hong Kong. The following are our recommendations:

1. Press conference and public seminars should be held to educate the public on the findings of this consultancy study;
2. An online link dedicated to occupational falls should be placed in the Council's website to disseminate occupational fall-related information, as well as all of our exercise videos;
3. OSH training courses on fall prevention should be provided to all industries, especially to the construction, catering, manufacturing and security industries;
4. Fall prevention should be a topic in all relevant safety-training courses. The instructor should educate all attendees on strategies to address various environmental, human (e.g. with our fall prevention exercise intervention programme), work-related, and management factors;
5. The Council should collaborate with the Labour Department and labour unions to contact those who have suffered workplace falls to engage in our exercise intervention once they have recovered from their injuries, as fall history is a major risk factor for subsequent falls;
6. The Council should also communicate with the Trade and Industry Department, various managers/contractors/manufacturers associations, and chambers of commerce to educate the employers to place greater emphasis on worker safety and fall prevention at workplace, as well as to promote our fall prevention programme to their employees;
7. Like the construction industry, other industries with high fall risk (e.g. catering, manufacturing, security, etc.) should also be advised to set up designated exercise session(s) to perform fall-prevention exercises;

8. A mobile app should be developed to send exercise video links and reminders to those who are interested in participating in our fall intervention programme. The app can also be used to track fall incidence for follow-up, or to incorporate interventions to prevent other types of work injuries.

12.1 Other considerations

Although we did not study the exact effect of training frequency on the overall effectiveness of our intervention, we believed that overall training volume (i.e. $2 \times 5 \times 12 = 120$ training sessions) should play a more significant role than training frequency (i.e. 2 sessions per day for 5 days a week) in reducing fall risk of the participants. Therefore, if a worker struggles to spare time to exercise twice a day for five days a week, we would recommend that individual to perform as many sessions as he/she can per week, and spread out the intervention period to a longer duration. For example, if someone could only spare 15 minutes per day for five days a week, he/she should alternate between the three training modules (i.e. static balance, dynamic balance, and resistance training) each day, and complete the whole intervention over a longer period of time (i.e. 24 weeks instead of 12 weeks, and progress to the next difficulty level every four weeks rather than every two weeks). This would provide more flexibility to those who have a busy work schedule and are too tired to engage in frequent exercise training. Alternatively, those who can spare longer exercise time may combine two exercise sessions into one longer session (i.e. static+dynamic or static+resistance) so they would only need to exercise once a day.

Furthermore, as shown in our cohort study, those who have high muscle strength would not gain too much benefit in engaging in our resistance training. It would be more beneficial for them to focus on improving their static and dynamic balance control, as these people do not lack sufficient muscle mass and strength for postural and gait control. Having even greater muscle strength and power will get them stronger, but these changes would have minimal effect on improving their balance and gait control.

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15 Appendix A: Using Virtual Trainer (webpage and mobile app)

For this OSHC project, we have modified Prof. Stanley Hui's Virtual Trainer (VT) mobile application and website to enhance user training experience. Virtual Trainer was originally designed to be an online platform to promote physical fitness for the general public. Based on some simple self-assessment results, suitable exercise trainings would be recommended to individual users. They could also modify their exercise prescriptions based on their personal needs. Through the mobile app, users could set up their own training routine based on their schedule, and the system would send notifications through SMS or email to prompt users to perform exercise training at the scheduled time. Inside VT, there is a reservoir of various exercises with video demonstrations, ranging from basic stretching, numerous warmup and cool-down routines, resistance training, aerobic exercises, daily physical activities, and other sport activities. Additionally, users can find various health and exercise-related information on the VT webpage.

Through the OSHC project, we have included our balance training exercised as detailed in [Chapter 8](#) into the VT system. Participants were told to install the VT mobile application onto their phones when they joined our fall prevention programme. VT would then be used to send reminders to users to prompt them to perform balance training at their predefined timeslots. YouTube links to our training were also provided so users would know exactly which training they would need to do at each exercise session. Participants were instructed to complete the reply form after each exercise session. For further details, the following slides were used to introduce the VT webpage and mobile application to our participants.

網上虛擬教練 Virtual Trainer vt.hk

『屹立不倒』防跌健體計劃

1

1: access vt.hk or www.vt.hk



2: 登入



填入所提供的用戶名稱

填入所提供的密碼

3



4

3.到會員區

VIRTUAL TRAINER
香港中文大學體育運動科學系

虛擬教練健體計劃
『屹立不倒』健體計劃
職業安全健康局
OCCUPATIONAL SAFETY & HEALTH COUNCIL

主頁 最新消息 甚麼是VT 健體計劃區 資源區 會員區 討論區

主頁 甚麼是VT 資源區 討論區

最新消息 健體計劃區 會員區

登入後，到“會員區”有關你的個人資料，我們已預先替你輸入

5

4: 個人資料

會員區

更改資料
VT 運動積分獎賞計劃
體適能測試區
測試報告

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*出生日期 1993 年 01 月 01 日
*欄位必須填寫

上傳圖片

取消 送出

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5. 到健體計劃區



主頁

甚麼是VT

資源區

討論區

最新消息

健體計劃區

會員區

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星期日	星期一	星期二	星期三	星期四	星期五	星期六
11月14日	11月08日	11月09日	11月10日	11月11日	11月12日	11月13日
卡路里消耗目標	卡路里消耗目標	卡路里消耗目標	卡路里消耗目標	卡路里消耗目標	卡路里消耗目標	卡路里消耗目標
標	標	標	標	標	標	標
0	0	0	0	0	0	0
累積分鐘	累積分鐘	累積分鐘	累積分鐘	累積分鐘	累積分鐘	累積分鐘
14	14	14	14	14	14	14
已選運動項目	已選運動項目	已選運動項目	已選運動項目	已選運動項目	已選運動項目	已選運動項目
2	2	2	2	2	2	2
檢視詳情	檢視詳情	檢視詳情	檢視詳情	檢視詳情	檢視詳情	檢視詳情

每節運動訓練必須於運動前加入5分鐘至10分鐘熱身活動，及於運動後加入5至10分鐘舒緩運動

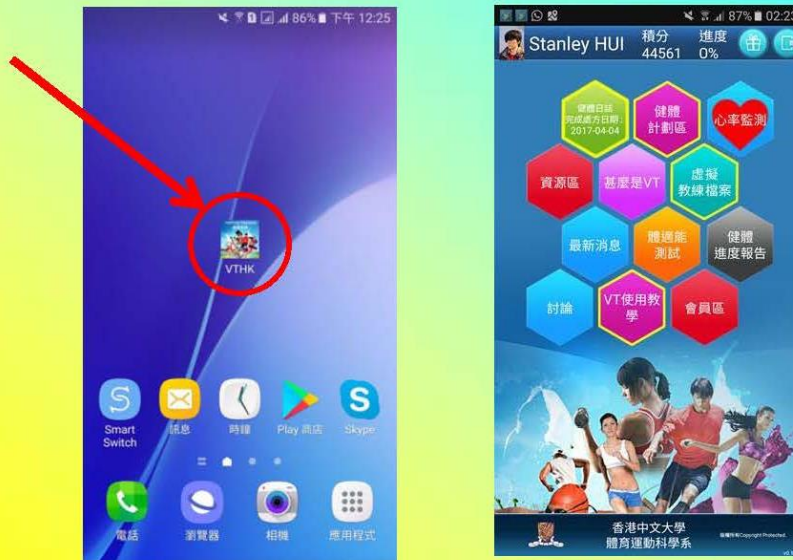
自行設定運動處方建議：應按自己的興趣、時間、身體狀況和能力，以量力而為。循序漸進的原則，去設計一套可行的個人運動處方。請按[+]開始訂立每星期的運動日子、時段及類型。

確定



6. 下載VT Apps

到 Google Play or App Store 下載 VT Apps
(search VTHK)



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i. 大家請根據自己名字旁邊的VTID登入應用程式，所有VTID的預設密碼同樣為0000

姓名	VT ID
郭嘉偉 Scott	tko01
Jenny NG 何佩玲	tko02
黃卓豪	tko03
張偉漢	tko04
沈冠榮	tko05
梁卓軒	tko06
楊耀輝	tko07
徐卓作	tko08
鄭家豪	tko09
李志偉	tko10
李卓恆	tko11
郭沛白	tko12
黃耀輝	tko13
蕭廷榮	tko14
李卓恆	tko15
陳偉	tko16
高偉傑	tko17
黃耀輝	tko18
丁國玉	tko19



ii. 登入畫面如上圖所示



iii. 登入後請選擇左上角的「健體日誌」

iv. 再按左上角的圖示
開啟設定



vi. 選擇「提醒處方安排」及
「訓練後提醒回覆處方」



v. 按「設定」

vii.a. 回到健體日誌，
可查看每天的運動處方
及未提交的處方回
覆



vii.b. 點擊運動即可進
入頁面提交處方回覆



viii. 提交處方回覆時，只需填上實際運
動時間及選擇主觀運動強度即可

7. 向VT教練匯報訓練進度



完成一定運動量後，憑運動積分，可換取虛擬獎品及真實獎品



8. 換領虛擬獎品



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會員每一次完成運動並向系統匯報，VT都會給予運動積分獎賞。當會員累積到一定的運動積分數量便可用運動積分來換領以下獎品。已換取獎品的運動積分會被扣除。



	實用VT獎品	所需要的運動積分
1.	Memo Pad	1000
2.	數跳繩	3000
3.	護腕錶	3000
4	計算機	4000