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PHYSICAL ACTIVITY, HEALTH AND EXERCISE

Descriptive epidemiology and correlates of children's swimming competence

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ABSTRACT

This study examined the swimming competence of primary school children, and how it was related to swimming activity, non-fatal aquatic events, and demographic factors. Primary school students (N = 4959; female = 2705, male = 2241; age range = 5 to 14 years) across 28 schools in the 15 districts of Hong Kong completed the Swimming Competence Questionnaire, and questions about their swimming experience, non-fatal aquatic events, and demographic variables. Descriptive statistics showed that over 60% of children could swim more than 5m, but less than 50% could swim over 25m. Over 50% of children were able to perform some basic swimming skills (e.g., holding breath underwater, floating, poolside/kick-board kicking, and treading water). Swimming competence was positively predicted by the demographic factors (i.e., age, sex, family income, and parents' highest education level), swimming experience, learning experience, and swimming location. Treading water was the only factor of swimming competence that established asignificant negative association with non-fatal aquatic events. Current results can be used to target key groups to improve children's swimming competence and reduce non-fatal aquatic events; children from lower socio-economic backgrounds and with less swimming experience should be encouraged to participate in more formal learn to swim lessons.

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Swimming ability; swim lesson; learn-to-swim; sport safety; drowning prevention

Swimming is one of the most popular sports for children (Australian Sports Commission, 2018; Bullough et al., 2015). Learning to swim or engaging in swimming has a wide range of health, social, psychological, and economical benefits (Barnsley et al., 2017; Lahart & Metsios, 2018). Moreover, it provides the opportunity for a child to engage in other aquatic sports (Australian Sports Commission, 2018; Bullough et al., 2015) and to develop personal aquatic survival skills that 1 day could save their life (Asher et al., 1995; Brenner et al., 2003). Despite these benefits, swimming is the top activity related to drowning (Royal Life Saving Society - Australia, 2017; Kerr et al., 2015; Wolf et al., 2009). Young children, among other age groups, have a high risk of unintentional drowning, both fatal and non-fatal (Tyler et al., 2017; Wang et al., 2019). Research also shows that swimming pools are the leading location for children's drowning in developed countries (Royal Life Saving Society -Australia 2017; Kerr et al., 2015; Wolf et al., 2009). The World Health Organization has therefore recommended that all school-aged children learn basic swimming skills in order to reduce the risk of drowning (World Health Organization, 2014). Given the benefits of swimming for young children, it is important to gain knowledge on young children's swimming competence levels, as well as an understanding of the factors that may be associated with their swimming competence. Current literature has not conducted a comprehensive investigation in this regard for young children; thus, a knowledge gap exists. The aim of the current study was to examine the swimming competence and its related factors in a representative sample of Hong Kong primary school students.

In examining the extant literature that has investigated the swimming competence of children, it seems that existing assessment methods for measuring children's swimming competence is limited, and measures often do not cover a range of skills such as swimming distance, competence in swimming strokes, and basic aquatic survival skills (Brenner & Committee on Injury, Violence, and Poison Prevention, 2003) ; Asher et al., 1995; Brenner et al., 2003; Fife & Goldoft, 1994; Irwin et al., 2009; Quan et al., 1989). For example, swimming competence has often been assessed by a single item asking individuals to report on their maximum swimming distance without stopping (Gilchrist et al., 2000; McCool et al., 2008) or on their subjective evaluation on swimming competence in terms of "none to strong" (Fife & Goldoft, 1994), "unable to swim" to "could swim competitively" (Irwin et al., 2009), and "non-swimmers" to "swimmers" (Langley & Silva, 1986). With these measures, a few studies report some general descriptive epidemiology of children's swimming competence and associations with demographic factors. Langley and Silva (1986) conducted a self-reported study among 941 mothers of 9 year-old children. It was reported that 29% of the children were either not able to swim or only able to swim for a few strokes (Langley & Silva, 1986) and that children who were able to swim were more likely to come from families of higher socioeconomic

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background. Fife and Goldoft (1994) conducted a survey among 6366 children aged between 5 and 14 years and found that 38% of the children were "non-swimmers" and 32% were "weak swimmers". The study also reported that age was a positive predictor of children's swimming competence; the older the child the higher the swimming competence. Although these studies provide some knowledge on the descriptive epidemiology and correlate of children's swimming competence, they are limited in providing knowledge on the broader scope of children's swimming competence, such as maximum swimming distance, swimming strokes, and basic swimming skills.

Other measures of swimming competence, such as *Swimming Scale* (Erbaugh, 1978) and *Can You Swim* questionnaire (Moran et al., 2012), provide a more comprehensive evaluation on individuals' swimming competence (i.e., more detailed assessment on swimming distance and basic swimming skills). However, their usage is often labour intensive (Erbaugh, 1978) and restricted to certain age groups (e.g., the *Swimming Scale* (Erbaugh, 1978) is used to assess pre-school-aged children) or swimming competence level (e.g., *Can You Swim* (Moran et al., 2012) questionnaire is suitable for people with at least entry standard swimming competence). Previous studies using these measures have therefore been unable to evaluate children's swimming competence in representative samples that typically involve large sample sizes and individuals with varied swimming competences. These limitations in the assessment have precluded a formal descriptive epidemiological study being undertaken that investigates children's swimming competence and how swimming competence may be related to factors such as swimming/learning experience, swimming location, demographic variables (e.g., age, sex, socio-economic status), and non-fatal aquatic events (i.e., swimming accidents).

Recently Chan et al. (2020) developed the first psychometrically validated questionnaire for the assessment of children's competence in swimming, namely the Swimming Competence Questionnaire (SCQ; Chan et al., 2020). SCQ is a self-reported questionnaire designed for assessing children's swimming competence in terms of swimming distance and basic swimming skills. Swimming distance in the SCQ reflects the distance children can swim by breaststroke, front-crawl, backstroke, and butterfly, and any combination of strokes; whereas swimming skills corresponds to whether or not children can perform basic swimming skills, including swimming underwater, holding breath underwater, floating, poolside kicking, kickboard kicking, and treading water. It is the first assessment of swimming competence that has gone through the robust examination of a wide range of validity tests and has shown to be applicable to young children regardless of their swimming competence (Chan et al., 2020). Therefore, using the SCQ may resolve the limitations of previous studies in the assessment of swimming competence as a more comprehensive and valid evaluation of children's competence is provided, allowing for higher quality descriptive epidemiological studies of children's swimming competence to be undertaken.

The current study

Swimming is a popular activity in young children but, moreover, is an important aquatic survival skill that could save a life (Asher et al., 1995; Brenner et al., 2003). Despite this, there is a knowledge gap on understanding the extent to which young children are competent in swimming, and how their swimming competence is related to factors such as swimming experience, learning experience, swimming location, demographic variables (age, sex, socio-economic status), and non-fatal aquatic events. In this descriptive epidemiological study, we aimed to:

(1) Report the descriptive statistics of children's swimming competence in terms of swimming distance and basic swimming skills.
(2) Examine how the overall swimming competence of children is related to swimming activity including swimming experience, learning experience, and swimming location, as well as to a range of demographic variables (age, sex, socio-economic status).
(3) Investigate what types of swimming competencies (e.g., swimming strokes or basic swimming skills) are related to non-fatal aquatic events.

It is hoped that the findings from this study will be of value to researchers of sports science, behavioural medicine, and injury prevention who seek to understand children's swimming competences and drowning prevention, as well as to healthcare professionals and public organisations who promote children's swimming competence for health and safety purposes.

Methods

Participants

We invited all registered local primary schools in Hong Kong (a total of 520 schools) to participate in the study, of which 28 schools across 15 districts in Hong Kong agreed to take part in the study. Participants from the 28 participating schools comprised a total of 4,959 students (age range = 5 to 14 years; male = 45.31%) across primary school grade 1 to primary school grade 6. See Table 1 for the demographic characteristics and swimming experience of the current sample.

Design and procedure

The study adopted a cross-sectional design using a parent assisted self-reported questionnaire. Part of our dataset has been used for a recent validation study of the SCQ (Chan et al., 2020), but the descriptive epidemiological findings in this study have not been reported. Ethical approval from the institutional review board of the first author's institution (no. UW16-407) was granted for the study. After consent was obtained from the parents and students, student participants were asked to complete a paper-based questionnaire at a time and location of their convenience and with the assistance of their parents. The questionnaire took about 20 minutes and comprised of items relating to study variables and demographic factors.

Table 1. Descriptive characteristics of the participants (N = 4959).

			N (%)	Mean (SD)		95% CI
Demographic Information						
Age				8.63 (1.71)		8.58–8.68
Sex						
Female			2705 (54.69%)			
Male			2241 (45.31%)			
School Grade						
Primary 1			913 (18.42%)			
Primary 2			796 (16.06%)			
Primary 3			888 (17.91%)			
Primary 4			1032 (20.82%)			
Primary 5			662 (13.35%)			
Primary 6			666 (13.44%)			
Parent highest education level						
Secondary or lower			1410 (44.42%)			
Post-school training college			421 (13.26%)			
University (undergraduate)			768 (24.20%)			
University (postgraduate)			575 (18.12%)			
Family income						
Low (≤ HKD $15,000)			500 (27.58%)			
Middle (HKD $15,000 – HKD $39,999)			672 (37.07%)			
High (≥ HKD $40,000)			641 (35.36%)			
Swimming Experience						
Age to start learning swimming				6.12 (1.77)		6.06–6.18
Years of swimming				2.79 (1.99)		2.72–2.85
Frequency of swimming (times per month)				2.88 (3.25)		2.77–2.99
Duration of swimming (mins per session)				74.92 (37.23)		73.76–76.08
Winter swimming			1177 (25.87%)			
Swimming Location						
Public swimming pools			3343 (67.41%)			
School swimming pools			561 (11.31%)			
Club swimming pools			1315 (26.52%)			
Estate swimming pools			1464 (29.52%)			
Beaches			1564 (31.54%)			
Swimming Accessibility						
Public swimming pools			2535 (51.12%)			
School swimming pools			437 (8.81%)			
Club swimming pools			1013 (40.43%)			
Estate swimming pools			1216 (24.52%)			
Beaches			514 (10.36%)			
Learning Experience						
Parent/guardian			1902 (38.35%)			
Swimming club			1346 (27.14%)			
Government class			1302 (26.26%)			
Private coach			1223 (24.66%)			
School/PE teacher			431 (8.69%)			
Sibling			260 (5.24%)			
Friend			204 (4.11%)			
Relative			203 (4.09%)			
Grandparent			114 (2.30%)			
Non-Fatal Aquatic Event			2046 (41.26%)			
Cuts/bruises			779 (38.07%)			
Out of breath			422 (20.63%)			
Fatigue			415 (20.28%)			
Non-fatal drowning			377 (18.43%)			
Muscle cramp			344 (16.81%)			
Anxiety/panic			155 (7.58%)			
Swimming Competence Index				45.86 (32.76)		44.87–46.85
Maximum Swimming Distance	General	Front-crawl	Breaststroke	Backstroke		Butterfly
Very Weak (0 m – 4.99 m)	37.15%	47.55%	50.71%	65.30%		80.71%
Weak (5 m – 12.49 m)	8.89%	6.73%	6.03%	3.40%		2.12%
Beginner (12.5 m – 24.99 m)	8.16%	6.35%	5.75%	3.57%		1.56%
Intermediate (25 m – 49.99 m)	13.98%	11.99%	10.73%	7.57%		5.39%
Good (50 m – 99.99 m)	14.72%	12.35%	12.55%	9.84%		5.24%
Excellent (>100 m)	17.09%	15.02%	14.24%	10.33%		4.98%
Mean Distance	67.63 m	58.41 m	50.59 m	32.05 m		13.17 m
[95% CI]	[63.02–72.14]	[54.59–62.44]	[47.37–54.51]	[29.79–34.29]		[11.99–14.32]
Swimming Skills	Poolside Kicking	Kicking With Kickboard	Holding Breath Underwater	Floating	Treading Water	Swimming Underwater
Able	87.69%	81.23%	81.35%	61.86%	56.79%	50.51%
Not Able	12.31%	18.77%	18.65%	38.14%	43.21%	49.49%

Note. SD = standard deviation, CI = bias-corrected and accelerated bootstrap confidence interval. PE teacher = physical education teacher. Maximum swimming distance indicates the maximum distance participants could swim without any assistance or rest. "General" indicates the maximum swimming distance by any stroke or combination of strokes. Mean Distance = Mean swimming distance in metres.

Measures

Swimming Competence

We used the Swimming Competence Questionnaire (Chan et al., 2020) to assess *swimming competence*. The SCQ is designed for children to complete themselves, with or without the assistance of an adult. Chan and colleagues conducted two large-scale studies with over six thousand children participants (aged between 5 and 14 years old) that provided support for the factor structure, convergent validity, concurrent validity, criterion validity, predictive validity, test–retest reliability, and ecological validity of the scale (Chan et al., 2020). Participants reported the maximum swimming distance (in metres) they could achieve without any assistance or rest using a *general stroke* (any stroke or combination of strokes) and using a single-specific stroke; *breaststroke, front-crawl, backstroke*, and *butterfly*. In addition, basic swimming skills were measured by asking participants to indicate whether they could perform *swimming underwater, holding breath underwater, floating, poolside kicking, kickboard kicking*, and *treading water*.

Swimming distance was scored on a 6-point Likert scale (0 = "very weak" to 5 = "excellent"). Basic swimming skills were scored on a dichotomous scale (0 = "I can't" and 1 = "I can"). *Swimming competence index* (Chan et al., 2020) was calculated based on the *scoring* of swimming competence variables (i.e., equation = 100 x ($General_{score}$ x 2 + MEAN($Front\text{-}crawl_{score}$, $Breaststroke_{score}$, $Backstroke_{score}$, $Butterfly_{score}$) x 2 + ($Poolside\ Kicking_{score}$ + $Kickboard\ Kicking_{score}$ + $Holding\ Breath\ Underwater_{score}$ + $Floating_{score}$ x 2 + $Treading\ Water_{score}$ x 2 + $Swimming\ Underwater_{score}$ x 3) ÷ 30)). The index ranges from 0 (i.e., "incompetent") to 100 (i.e., "competent"), with a higher score indicating better swimming competence (Chan et al., 2020).

Swimming Experience

For swimming experience, participants reported their *frequency of swimming* (i.e., "How often do you swim?", scored as number of times per month), *swimming duration* (i.e., "How long do you swim in each session?", scored in minutes per session), participation in *winter swimming* (i.e., "Do you swim during the winter season?", scored 1 = yes and 0 = no), *years of swimming* (i.e., "At what age did you learn swimming?", scored in years of swimming by subtracting age from this variable).

Swimming Location and Swimming Accessibility

For swimming location and swimming accessibility, participants reported whether or not they swam in these *swimming locations* (i.e., "Where do you swim?") and whether or not these locations were *accessible* to them (i.e., "Is it near or convenient to go?"), in a list of common swimming locations (e.g., public swimming pool, school swimming pool, clubhouse swimming pool facilities, estate swimming pool facilities, beach). Responses were scored 1 = yes and 0 = no for each of the swimming locations and accessibility to each of these locations.

Learning Experience

For learning experience, participants reported their *learning experience* by selecting from a list of key agents (i.e., parent/guardian, swimming club, government class, private coach, school/physical education teacher, grandparent, relative, sibling, friend) who had delivered swimming instruction to them in the past (i.e., "Did you receive training or instruction from … ?). Responses were coded 1 = received swimming instruction from the agent and 0 = did not receive swimming instruction from the agent.

Demographic Factors

A number of demographic details were collected: age of child (in years), sex of child, primary school grade, parent education level (recorded for the parent with the highest level of education level in the household), and family income.

Non-Fatal Aquatic Events

For the assessment of *non-fatal aquatic events*, participants responded to the item (i.e., "Have you experience any accidents or injury from swimming"?) by circling a list of common aquatic events (e.g., non-fatal drowning, muscle cramps, fatigue, out-of-breath, cuts-or-bruises, and anxiety or panic) or writing it down for unstated "other" incidents. Responses were coded 1 = presence of non-fatal aquatic events and 0 = absence of non-fatal aquatic events.

Data analysis

Descriptive statistics regarding swimming competence and number of non-fatal aquatic events were measured using mean, standard deviation (SD), percentage and 95% confidence interval (CI). Preliminary analysis using measures of skewness and kurtosis revealed that our swimming competence data were not normally distributed. Thus, we estimated the 95% CIs of the descriptive statistics of the swimming-related variables using bias-corrected and accelerated bootstrapping with 1,000 resampling in order to protect the estimations against non-normality (Diciccio & Romano, 1988). We employed hierarchical multiple regression and logistic regression to examine whether the factors were associated with swimming competence and non-fatal aquatic events. In the regression models, demographic factors (i.e., age, sex, parents; highest education level, and family income) were placed as independent variables in Step 1 for controlling the potential confounding effects of demographic factors, and other independent variables of swimming experience, swimming competence (for the prediction of non-fatal aquatic event only), swimming location, swimming accessibility, and learning experience were placed in Step 2, respectively, in separate models. The dataset and scoring tool associated with the analysis of this study are available online in the OSF platform (https://osf.io/vdpgw/).

Results

Descriptive statistics

Descriptive Statistics of Swimming Competence

For swimming competence, participants were able to swim on average of 67.63 metres (95% CI = 63.02–72.14) in the general stroke category. It can also be seen that the maximum swimming distance (in metres) of the specific swimming strokes of front-crawl and breaststroke were longer than backstroke and

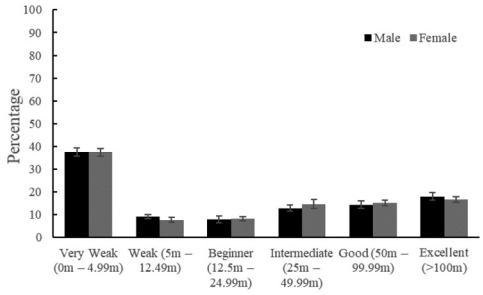

Figure 1a. General Stroke Swimming Distance by Sex

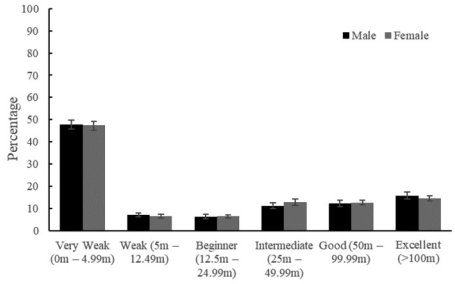

Figure 1b. Front-crawl Swimming Distance by Sex

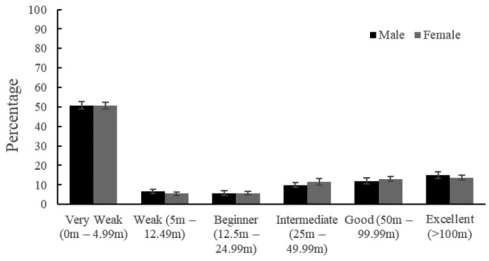

Figure 1c. Breaststroke Swimming Distance by Sex

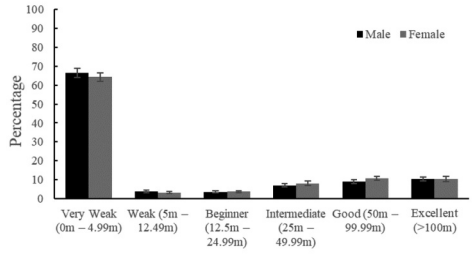

Figure 1d. Backstroke Swimming Distance by Sex

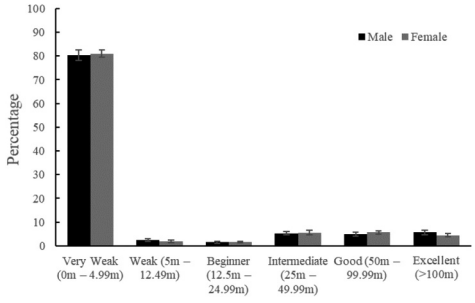

Figure 1a-e. Maximum swimming distance by stroke and sex. Error bars represent bias-corrected and accelerated bootstrap confidence intervals.

butterfly (see Table 1). Findings also showed that over 50% of participants were unable to swim further than 25 metres using general stroke (54.20% unable), with even fewer reported for specific single strokes: front-crawl (60.63% unable), breaststroke (62.49% unable), backstroke (72.27% unable), and butterfly (84.39% unable). Furthermore, a sizable number of participants indicated that they cannot swim further than 5 metres using general stroke (37.15% unable), with even fewer reported for the specific single strokes: front-crawl (47.55% unable), breaststroke (50.71% unable), backstroke (65.30% unable), and butterfly (80.71% unable) strokes. Figure 1a-e display the portions of children who could achieve certain categories of maximum swimming distance by strokes and sex. In terms of basic swimming skills, over 80% of participants were able to perform poolside kicking (87.69% able), kickboard kicking (81.23% able), and holding their breath underwater (81.35% able), with over 60% reporting that they can perform floating (61.86% able), and just over half reporting that they can tread water (56.79% able) and swim underwater (50.51% able). Appendix A, Appendix B, and Appendix C, respectively, display the descriptive statistics (by sex and grade) of maximum swimming distance, basic swimming skills, and swimming competence index.

Predictive statistics

Prediction of Swimming Competence

In the prediction of swimming competence, hierarchical multiple regression showed the demographic factors of age (β =.31, $p < .01$), sex (β = .04, $p < .05$), parent highest education level (β = .15, $p < .01$), and family income (β = .14, $p < .01$) were significant predictors in Step 1 (R^2 = .28). In Step 2, the independent variables of swimming experience (ΔR^2 = .33, $p < .01$), swimming location (ΔR^2 = .09, $p < .01$), swimming accessibility (ΔR^2 = .06, $p < .01$), and learning experience (ΔR^2 = .24, $p < .01$) significantly increased the variance explained in swimming competence (total R^2 = .26 to.47, $p < .01$). Table 2 displays the standardised beta estimates, 95% CI of unstandardised beta, F-statistics, and the effect sizes of the hierarchical multiple regression models.

Prediction of Non-Fatal Aquatic Events

In the prediction of non-fatal aquatic events, hierarchical logistic regression showed the demographic factor of age (OR = 1.26, $p < .01$) as the only significant predictor in Step 1. Swimming duration (OR = 1.01, $p < .01$) was the only significant factor of swimming experience in Step 2. In Step 3, treading

Table 2. Results of hierarchical linear multiple regression models.

Dependent Variable = Swimming Competence								
Step	Independent Variables	β	95% CI of B	F	ΔF	R^2	ΔR^2	VIF
Demographic Factors								
1	Age	.31**	4.46–5.84	96.24**	N/A	.28	N/A	1.54
	Sex	.04*	.01–4.38					1.01
	Parents' highest education	.15**	3.02–5.30					1.03
	Family Income	.14**	1.08–1.90					1.04
Swimming Experience								
2	Years of swimming	.32**	3.68–4.75	257.80**	360.62**	.47	.33	1.53
	Frequency of swimming	.23**	1.60–2.14					1.01
	Swimming duration	.03	.00 –.05					1.06
	Winter swimming	.30**	14.78–18.97					1.02
Swimming Location								
2	Public swimming pool	.14**	7.83–11.900	188.17**	104.54**	.28	.09	1.03
	School swimming pool	.25**	22.34–27.52					1.06
	Club swimming pool	.14**	8.53–12.54					1.09
	Estate swimming pool	.08**	3.77–7.82					1.05
	Beach	−.03*	−3.90 – −.27					1.01
Swimming Accessibility								
2	Public swimming pool	.12**	6.00–9.59	164.76**	70.66**	.26	.06	1.03
	School swimming pool	.17**	16.13–22.03					1.05
	Club swimming pool	.13**	8.20–12.14					1.07
	Estate swimming pool	.07	3.57–7.54					1.06
	Beach	−.02	−5.38 – −.03					1.01
Learning Experience								
2	Parent/guardian	−.03**	−3.77 – −.72	233.47**	179.00**	.43	.24	1.01
	Swimming club	.38**	25.46–28.79					1.02
	Government class	.21**	13.81–17.26					1.01
	Private coach	.31**	21.56–25.34					1.06
	School/PE teacher	.08**	5.62–11.29					1.03
	Grandparent	−.00	−5.29–4.88					1.00
	Relative	−.01	−5.68–1.61					1.01
	Sibling	.01	−.97–5.33					1.01
	Friend	−.01	−5.91–1.71					1.01

Note. Step 1 was identical throughout the three models. CI of B = 95% bias-corrected and accelerated bootstrap confidence interval of unstandardized beta. VIF = variance inflation factor. Swimming duration = duration of each swimming session in minutes. Learning experience = "Learn swimming from whom?". PE teacher = physical education teacher. *p <.05; **p <.01.

water of swimming competence (OR = .77, p < .01) and school/physical education teachers of learning experience (OR = 1.53, p < .01) were both significant predictors of non-fatal aquatic events. None of the variables in swimming location and swimming accessibility were significant predictors of non-fatal aquatic events. Table 3 displays the chi-squares, effect size, and 95% confidence interval of the odd ratios in the logistic regression models.

Discussion

Given the health and safety benefits of swimming and its popularity (Ashbullby et al., 2013; Bullough et al., 2015; Lahart & Metsios, 2018; Morrongiello et al., 2013; Wang et al., 2019), examining the swimming competence of young children is highly important. The aim of the current study was to investigate the swimming competence and its related factors (i.e., swimming experience, learning experience, swimming location, demographic variables (age, sex, socio-economic status), and non-fatal aquatic events) in a representative sample of Hong Kong primary school students. Current results add to our understanding about children's swimming competence and its related factors (Brenner & Committee on Injury, Violence, and Poison Prevention, 2003; Brenner et al., 2003; Irwin et al., 2009). The relationships between swimming competence and non-fatal aquatic events are especially important given the empirical literature to date has primarily focused on factors related to fatal drowning (Brenner et al., 2003; Peden & McGee, 2003; Petrass & Blitvich, 2014; Tyler et al., 2017). This knowledge can be used to design programmes that aim to improve the swimming competence of young children as well as reduce the risk of young children experiencing adverse aquatic events.

Descriptive and demographic factors

Overall Swimming Competence of Primary School Children in Hong Kong

Current findings showed that the swimming competence of about 37% of primary school children in Hong Kong was classified as very weak, indicating they could only swim a distance of 0 m – 4.99 m. This percentage is comparable to other countries; in the 38 USD% of children aged 14 years or younger were reported as non-swimmers (Fife & Goldoft, 1994) and 37% of adults aged 18 years and older had very limited swimming competence (i.e., maximum swimming distance is zero) (Gilchrist et al., 2000). Such findings might imply that lack of swimming competence may track across childhood to adulthood, similar to studies in the physical activity area where childhood physical activity has been shown to be related to adolescent and adulthood physical activity (Telama et al., 2014, 2005). This has important implications on teaching swimming and aquatic survival skills more broadly at a young age. These swimming and aquatic survival skills might be as important as the fundamental movement skills that are well acknowledged to

Table 3. Results of hierarchical logistic regression models.

Dependent Variable = Non-Fatal Events							
Step	Variables	Odds Ratio	95% CI of EXP (B)	Wald	χ^2	R^2	ΔR^2
Demographic Factors							
1	Age	1.26**	1.18–1.34	49.05	89.06**	.047	N/A
	Sex	.86	.73–1.02	3.19			
	Parents' highest education	.92	.83–1.01	3.14			
	Family income	.99	.96–1.03	.18			
Swimming Experience							
2	Years of swimming	.98	.93–1.01	.87	103.42**	.055	.008
	Frequency of swimming	1.00	.98–1.03	.09			
	Swimming duration	1.01**	1.00–1.01	10.71			
	Winter swimming	1.12	.93–1.35	1.33			
Swimming Competence							
3	General	.99	.87–1.13	.02	120.61**	.064	.017
	Breaststroke	.97	.89–1.06	.34			
	Front-crawl	.99	.90–1.09	.02			
	Backstroke	1.06	.98–1.14	2.17			
	Butterfly	1.05	.98–1.12	1.54			
	Swimming underwater	.87	.72–1.07	1.78			
	Floating	1.04	.70–1.55	.03			
	Poolside kicking	.96	.75–1.22	.13			
	Kickboard kicking	1.21	.72–2.03	.52			
	Holding breath underwater	1.14	.77–1.70	.41			
	Treading water	.77**	.63 –.95	5.93			
Swimming Location							
3	Public swimming pool	1.09	.91–1.32	.85	113.71**	.058	.011
	School swimming pool	1.12	.92–1.36	1.29			
	Club swimming pool	1.17	.93–1.47	1.70			
	Estate swimming pool	1.06	.88–1.27	.36			
	Beach	1.12	.94–1.34	1.67			
Swimming Accessibility							
3	Public swimming pool	1.13	.95–1.33	1.86	111.46**	.057	.010
	School swimming pool	1.23	.96–1.57	2.59			
	Club swimming pool	.98	.81–1.19	.03			
	Estate swimming pool	1.14	.95–1.37	1.96			
	Beach	.94	.73–1.22	.21			
Learning Experience							
3	Parent/guardian	1.18	.99–1.40	3.39	131.23**	.067	.020
	Swimming club	1.19	.98–1.45	3.24			
	Government class	1.08	.90–1.30	.65			
	Private coach	1.06	.88–1.27	.33			
	School/PE teacher	1.53**	1.18–1.98	1.09			
	Grandparent	1.18	.69–2.02	.37			
	Relative	1.39	.90–2.15	2.18			
	Sibling	1.28	.88–1.84	1.70			
	Friend	1.09	.71–1.68	.17			

Note. Controls are age, gender, grade, parents' education, income and years, frequency, duration of swimming and winter swimming. Steps 1 and 2 were identical throughout the three models. R^2 = Nagelkerke R-squared. 95% CI of EXP (B) = 95% confidence interval of the odds ratio. Learning experience = "Learn swimming from whom?". PE teacher = physical education teacher.
*p <.05; **p <.01.

be highly important for children's healthy growth and development (Lubans et al., 2010). Future cohort studies should examine this speculation by longitudinally following-up the swimming competence and health of children.

Socio-Economic Status and Swimming Competence

Further, current findings indicated that children with greater competence in their swimming competence tended to be from families with higher income and parental education levels. Low socioeconomic status and education levels are well documented as factors associated with disparities in the participation of physical activity in both children and adults (Brodersen et al., 2007; Gordon-Larsen et al., 2006; Marmot, 2002), and, thus, may explain current findings given swimming is an activity with considerable potential to promote increased physical activity in young people. In addition, providing children with opportunities to engage in regular swimming can demand greater time from parents (e.g., supervision or attention, transportation to swimming facilities) as well as financial resources (e.g., tuition/coaching fee), both of which have been shown to be associated with socioeconomic status and education levels (Irwin et al., 2009).

Age and Swimming Competence

Our findings also showed that although older children had better swimming competence they also had a heightened risk of experiencing a non-fatal aquatic event. Previous studies have reported better swimming competence among older children compared to younger children (Irwin et al., 2009; Moran et al., 2012), yet also have shown that older children have more occasions to swim without adult supervision thus potentially increasing the risk of non-fatal aquatic events (Brenner &

Committee on Injury, Violence, and Poison Prevention, 2003; Ashbullby et al., 2013). In support of this suggestion, a recent report in China showed that the mortality rate of drowning in older children (aged 10 to 14 years) was slightly higher than in younger children (aged 5 to 9 years)(Wang et al., 2019). Similarly, other studies have demonstrated a higher risk of unintentional drowning in the adolescent years compared to the childhood years (Quan & Cummings, 2003).

Sex and Swimming Competence

Current findings further showed that boys had significantly better swimming competence compared to girls. Although small, this gender effect is consistent with prior studies (Erbaugh, 1978; Gilchrist et al., 2000). In contrast, a gender difference in the risk of non-fatal aquatic event was not found. A previous study reported that male students tended to perceive a lower risk of drowning than female students, although no gender difference was observed in swimming competence (Moran et al., 2012). In another study, men compared to women were found to have statistically significantly higher intentions and attitudes and significantly lower barrier self-efficacy, risk perception, anticipated regret, perceived susceptibility, and perceived severity to engage in a known risky drowning behaviour of driving through floodwater (Hamilton et al., 2018). Future research, therefore, should continue to explore gender differences in perceptions of risky aquatic behaviours. In sum, based on current findings, it is important to recognise that greater swimming competence in older or male children does not preclude them from being at-risk of experiencing non-fatal (or even fatal) aquatic events and that supervision of children in and around water, irrespective of age or gender, is needed (Brenner & Committee on Injury, Violence, and Poison Prevention, 2003 ; Ashbullby et al., 2013; Blanksby et al., 1995; Moran et al., 2012; Quan & Cummings, 2003).

Key factors in the prediction of swimming competence and non-fatal aquatic events

Swimming Experience

Aligning with previous research, years of swimming, swimming frequency, and winter swimming was positively related to children's swimming competence (Bullough et al., 2015; Fife & Goldoft, 1994). On the contrary, these factors were not shown to be significant predictors of non-fatal aquatic events, rather the duration of each swimming session was found to positively correlate with non-fatal aquatic events. Although it should be noted that the effect was very small and swimming duration was not a significant predictor of swimming competence. A possible explanation for these findings could be that children who are more competent in swimming started to learn swimming at an earlier age, and swam more frequently throughout all seasons (e.g., winter) are less likely to be at risk of experiencing a non-fatal aquatic event. This, however, may be contingent upon the duration of each swimming session as swimming duration was positively associated with non-fatal aquatic events. It could be that longer periods of time in the water might lead to fatigue or other negative outcomes such as hypothermia which, in turn, might increase the possibility of experiencing an adverse event. Future research should continue to examine the effects of swimming duration and its relationship to non-fatal aquatic events, only then can we start to target time spent swimming in reducing non-fatal aquatic events.

Swimming Location and Accessibility

Swimming location (all locations) and accessibility of swimming facilities (public, school, and club swimming pools) were significantly associated with swimming competence. Hong Kong is a city that provides a wide range of swimming locations and good access to both public and private swimming facilities. For example, there are swimming pools or beaches located in every Hong Kong district. It is notable that in this study, as is the case in Hong Kong generally, participants more often swam in public swimming facilities (67%) than at beaches or privately owned pools. Public swimming facilities often provide life-saving services (Quan et al., 1989; Schwebel et al., 2007) whereas such services in the latter locations are scare. This may explain why swimming location and accessibility were not significantly associated with non-fatal aquatic events in this study. It could also explain why socioeconomic factors such as family income and parents' education level were not significantly associated with non-fatal aquatic events, as life-saving services at public swimming facilities are provided at no extra cost. Given previous research has found family income to be negatively associated with fatal drownings at swimming pool locations (Saluja et al., 2006), more research is needed to better understand the role of sociodemographic factors on fatal and non-fatal drownings.

Learning Experience

For learning experience, children's swimming competence was significantly associated with attending swimming lessons organised by swimming clubs, private coaches, or the government, with learning experiences provided by parents/guardians and school/physical education teachers also being predictive but effects were small. On the other hand, children who learnt swimming from school/physical education teachers were at least 50% more likely to experience non-fatal aquatic events than other children. This finding has important implications for the teaching of children's swimming and suggests that lessons are perhaps better undertaken by qualified swimming instructors and at professional swimming clubs (Asher et al., 1995; Brenner et al., 2003, 2009; Bullough et al., 2015; Morrongiello et al., 2013).

The extant has, in general, shown consistent support for the role of swimming competence on the prevention of fatal drownings (Brenner et al., 2003, 2009; Fife & Goldoft, 1994; Irwin et al., 2009; Rubio et al., 2015). Current findings, however, indicated that not all types of swimming competence are linked to non-fatal aquatic events. Furthest swimming distance and the majority of the basic swimming skills were not shown to be significant predictors of non-fatal aquatic events. Interestingly, treading water was the only swimming competence to be associated with non-fatal aquatic events, with strong effects observed. Specifically, children who were able to tread water were 23% less likely to experience non-fatal aquatic events than children who were unable to tread water. Based on these findings, it could be argued that more focus is needed

on teaching basic aquatic survival skills (Brenner & Committee on Injury, Violence, and Poison Prevention, 2003 ; Asher et al., 1995; Petrass & Blitvich, 2014), in particular treading water.

Limitation and future directions

Several limitations of the current study should be noted. The study sample, although representative of Hong Kong urban schools, comprised of children from regular primary schools in Hong Kong. Thus, current findings may not generalise to children from rural schools and/or schools that cater for children with disabilities. Further, the majority of the sample was Chinese. Previous studies have reported racial disparities regarding drowning (Saluja et al., 2006); thus, it would be important for future studies to extend this research to other ethnic minority groups in Hong Kong to allow assessment of cross-cultural comparisons (Chan et al., 2017; Chan, Yang et al., 2015). The use of self-report data and retrospective measures of swimming competence and non-fatal aquatic events may raise concerns about social desirability, recall and response bias, and general response tendencies (Chan, Ivarsson et al., 2015; Chan et al., 2020). Although the self-reported swimming competence measured by SCQ was highly correlated with coaches' ratings (Chan et al., 2020), it is important for future studies to further refine SCQ and explore methods to objectively measure swimming competence and non-fatal events. The cross-sectional design of the study precludes drawing inferences about causality among the associations identified, calling for future to adopt longitudinal or experimental studies that can confirm current findings.

Conclusion

Our study revealed important epidemiological findings regarding factors related to the swimming competence and non-fatal aquatic events of primary school children. Higher family income and parent education level were associated with better swimming competence. Older children had better swimming competence but they also reported greater experience of non-fatal aquatic events. Certain factors related to swimming competence (trending water), swimming experience (swimming duration), and swimming experience (school/physical education teachers) were associated with the experience of non-fatal aquatic events. To improve children's swimming competence, it may be beneficial to provide children with more opportunities to engage in swimming. Subsidised learn-to-swim programmes should prioritise families from lower socioeconomic status to address the disparity of the children' participation and competence of swimming. Swimming training that focuses on basic aquatic survival skills, such as treading water, may help in reducing the risk of non-fatal aquatic events.

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Disclosure statement

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Appendix A. Maximum swimming distance by sex and school grade.

	General	Front-crawl	Breaststroke	Backstroke	Butterfly
Sex					
Male (N = 2241; M-age = 8.49)	72.81 m [65.43–80.20]	62.88 m [55.43–70.26]	54.67 m [48.42–61.16]	33.05 m [28.15–37.88]	13.63 m [11.74–15.56]
Female (N = 2705 M-age = 8.06)	63.5 m [57.06–70.18]	54.83 m [49.15–61.35]	47.99 m [43.16–53.17]	31.28 m [28.22–34.74]	12.81 m [11.30–14.36]
School Grade					
Primary 1 (N = 913; M-age = 6.17)	16.63 m [12.39–23.62]	15.06 m [10.97–21.12]	11.86 m [8.34–16.98]	8.05 m [5.43–11.65]	2.22 m [1.12–3.69]
Primary 2 (N = 796; M-age = 6.99)	46.39 m [40.41–51.92]	41.17 m [35.40–46.79]	31.67 m [27.31–36.44]	20.52 m [17.43–23.55]	7.23 m [5.86–8.54]
Primary 3 (N = 888; M-age = 8.31)	51.53 m [39.31–65.81]	45.96 m [33.51–61.15]	39.22 m [30.47–49.77]	27.01 m [20.67–34.49]	9.77 m [7.07–12.54]
Primary 4 (N = 1032; M-age = 9.27)	71.73 m [64.44–78.40]	60.88 m [54.22–67.26]	53.51 m [48.00–58.63]	32.16 m [25.43–41.09]	13.47 m [10.22–16.93]
Primary 5 (N = 662; M-age = 10.29)	114.26 m [103.03–125.91]	100.78 m [89.81–111.94]	89.2 m [79.69–98.86]	56.38 m [44.17–68.85]	25.11 m [19.16–32.24]
Primary 6 (N = 666 M-age = 11.14)	131.71 m [119.50–143.82]	109.07 m [97.78–120.70]	101.22 m [91.13–111.69]	61.02 m [54.47–67.80]	27.34 m [23.99–30.87]

Note. Values are mean (95% bias-corrected and accelerated bootstrap confidence interval). Maximum swimming distance indicates the maximum swimming distance participants could swim without any assistance or rest. "General" indicates the maximum swimming by any stroke or combination of strokes. M-age = mean age of the category.

Appendix B. Swimming skills by sex and school grade.

Swimming Skills		Poolside Kicking	Kicking With Kickboard	Holding Breath Underwater	Floating	Treading Water	Swimming Underwater
Sex							
Male	Able	1817 (81.08%)	1684 (75.15%)	1716 (76.57%)	1262 (56.31%)	1173 (52.34%)	1052 (46.94%)
	Not Able	424 (18.92%)	557 (24.86%)	525 (23.43%)	979 (43.69%)	1068 (47.66%)	1189 (53.06%)
Female	Able	2298 (84.95%)	2117 (78.26%)	2121 (78.41%)	1587 (58.67%)	1443 (53.35%)	1276 (47.17%)
	Not Able	407 (15.05%)	588 (21.74%)	584 (21.59%)	1118 (41.33%)	1262 (46.65%)	1429 (52.83%)
School Grade							
Primary 1	Able	637 (69.77%)	551 (60.35%)	511 (55.97%)	311 (34.06%)	274 (30.01%)	224 (24.54%)
	Not Able	276 (30.23%)	362 (39.65%)	402 (44.03%)	602 (65.94%)	639 (69.99%)	689 (75.47%)
Primary 2	Able	648 (81.41%)	615 (77.26%)	592 (74.37%)	422 (53.02%)	368 (46.23%)	295 (37.06%)
	Not Able	148 (18.59%)	181 (22.74%)	204 (25.63%)	374 (46.90%)	428 (53.77%)	501 (62.94%)
Primary 3	Able	738 (83.11%)	683 (76.91%)	701 (78.94%)	486 (54.73%)	443 (49.89%)	414 (46.62%)
	Not Able	150 (16.89%)	205 (23.09%)	187 (21.06%)	402 (45.27%)	445 (50.11%)	474 (53.38%)
Primary 4	Able	884 (85.66%)	826 (80.04%)	837 (81.11%)	637 (61.73%)	589 (57.07%)	536 (51.94%)
	Not Able	148 (14.34%)	206 (19.96%)	195 (18.90%)	395 (38.28%)	443 (42.93%)	496 (48.06%)
Primary 5	Able	598 (90.33%)	558 (84.29%)	594 (89.73%)	489 (73.87%)	472 (71.30%)	428 (64.65%)
	Not Able	64 (9.67%)	104 (15.71%)	68 (10.27%)	173 (26.13%)	190 (28.70%)	234 (35.35%)
Primary 6	Able	616 (92.49%)	573 (86.04%)	605 (90.84%)	507 (76.13%)	473 (71.02%)	430 (64.56%)
	Not Able	50 (7.51%)	93 (13.96%)	61 (9.16%)	159 (23.87%)	193 (28.98%)	236 (35.44%)

Note. Values are N (%).

Appendix C. Swimming competence index by sex and school grade.

		Swimming Competence Index
Sex		
	Male	45.74 [44.33–47.22]
	Female	45.99 [44.49–47.68]
School Grade		
	Primary 1	24.18 [22.43–26.05]
	Primary 2	39.40 [37.06–41.90]
	Primary 3	43.83 [41.36–46.21]
	Primary 4	48.81 [46.70–50.92]
	Primary 5	61.75 [59.47–64.36]
	Primary 6	61.53 [59.99–64.18]

Note. Values are mean (95% bias-corrected and accelerated bootstrap confidence interval).