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Clustering patterns of behavioural risk factors for cardiovascular diseases in Bangladeshi adolescents: A population-based study

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ABSTRACT

Objectives: To examine the clustering of major behavioural risk factors for cardiovascular diseases (CVD) among adolescents in Bangladesh.
Methods: Nationally representative data from the 2014 Bangladesh Global School-based Student Health Survey were analysed in 2,978 adolescents (mean age: 14.2 SD 0.99; 60.0% females). We compared the observed (O) to expected (E) prevalence ratios of 64 possible combinations of the six behavioural risk factors (i.e., physical inactivity, sedentary behaviour, tobacco smoking, alcohol drinking, low fruit and vegetable intake, and overweight/obesity) to determine their clustering patterns. Poisson regression was used to examine the associations.
Results: The most common single risk factor was low fruit and vegetable intake, followed by physical inactivity (87% and 59%, respectively). Overall, 18% of the adolescents had three or more risk factors, with males reporting higher prevalence than females (21% vs. 11%). The simultaneous occurrence of low fruit and vegetable intake, and physical inactivity was 30% greater in males (O/E ratio: 1.3, 95% CI: 1.2–1.4) and 20% greater in females (1.2, 1.2–1.3) than what was expected if there was no clustering. The analysis also demonstrated clustering of low fruit and vegetable, overweight/obesity, and high sedentary behaviour (2.5, 1.3–4.9), and low fruit and vegetable, overweight/obesity, and physical inactivity (1.4, 1.1–2.0) for males.
Conclusions: This study fills the gap in the scientific literature by providing evidence that behavioural risk factors tend to cluster among adolescents in Bangladesh. Early prevention programs with evidence-based strategies need to target adolescents who are at a greater risk of engaging in multiple risk behaviours.

Introduction

Cardiovascular diseases (CVDs) are the leading causes of global mortality, which contribute significantly towards the global burden of disease [1]. In 2016, CVDs were attributable to an estimated 17.9 million deaths, which represents about one-third (31%) of all deaths worldwide [2]. Between 2007 and 2017, globally, deaths due to CVDs increased by 21.1% [1]. People in low- and middle-income countries are disproportionally affected by CVDs, where about three-quarters of CVD deaths take place [2]. In these resource-poor countries, management and control of CVDs remain a major public health challenge given their escalating costs of medical care in addition to indirect costs of premature deaths and disability [2]. Most of the CVDs are preventable by addressing the concomitant behavioural risk factors such as obesity, cigarette smoking, harmful use of alcohol, unhealthy diet, and a sedentary lifestyle characterised by insufficient physical activity [2]. While each of the behavioural risk factors contributes as a precursor of CVDs, these factors may co-occur and cluster [3,4]. The simultaneous occurrence of these risk factors can present a higher risk of CVD mortality and morbidity [3,4].

The clinical manifestations of CVDs usually occur during adulthood; however, most of the precursors of CVDs are common among adolescents [5] with the evidence of simultaneous occurrence of these risk behaviours during adolescence [5–8]. While individual behaviours adopted during the formative years of life tend to track into adulthood [9,10], clustering of these risk factors in adolescents is known to accelerate atherogenesis, which has been associated with increased risk of type 2 diabetes mellitus and elevated blood pressure in adulthood [11]. Thus, early identification of these risk factors and their clustering patterns during adolescence can be vital to control, manage, and prevent the future burden of

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CVDs. However, there is a scarcity of relevant data in many low- and middle-income countries, which is likely to hinder the formulation of appropriate strategies to prevent CVDs in the regions.

Bangladesh, a lower-middle-income country in South Asia, is going through an unprecedented rate of economic growth, urbanisation, industrialisation, and associated changes in lifestyle behaviours in the past few decades. The CVD-related mortality in Bangladesh, due to stroke and myocardial infarction, has increased significantly from 11 per 10,000 person in 1986 to 411 per 10,000 in 2006 [12]. People in Bangladesh had a lower mean age (51.9 years) for acute myocardial infarction than the global estimated mean age of 58.1 years [13]. Twenty-one per cent of adults in Bangladesh reported having hypertension [14], which is a major risk factor for myocardial infarction and other CVDs. Compared to their neighbours in other South Asian countries, people in Bangladesh had the highest prevalence of CVD risk factors [13] with 93% of adults consuming an inadequate amount of fruit and vegetable, 44% using tobacco, and 38% having insufficient physical activity [14]. About three-quarter of adults (76%) in Bangladesh are exposed to at least two major behavioural risk factors of CVDs, while over one-third (38%) have three or more risk factors [14].

A number of studies have addressed the prevalence of isolated risk behaviours including physical inactivity (15), sedentary behaviour [16], smoking [17], and obesity [18] among adolescents in Bangladesh with little or no information about the other risk factors such as low fruit and vegetable intake, and alcohol consumption. An earlier study examined the clustering pattern of non-communicable disease (NCD) risk behaviours among adults aged ≥25 years in Bangladesh [14]; however, no study has looked into the coexistence of behavioural risk factors of CVDs among the country's adolescents. This study aimed to estimate the prevalence of six risk behaviours (i.e., physical inactivity, sedentary behaviour, tobacco smoking, alcohol drinking, low fruit and vegetable intake, and overweight/obesity) of CVDs and examine their clustering patterns among adolescents in Bangladesh.

Data and methodology

Data source

We used publicly available nationally representative Bangladesh Global School-based Student Health Survey (GSHS) data collected in 2014. The GSHS is a World Health Organization (WHO) and the United States Centers for Disease Control and Prevention (US CDC) joint initiative in collaboration with various UN allies. The GSHS used an anonymous and self-administered questionnaire with a set of core questionnaire modules addressing the leading causes of adolescents' poor health worldwide including items on behavioural risk factors of CVDs [19]. Country-specific examples, options, or phrasings were included in the questionnaire to ensure that the questionnaire items were socio-culturally adaptable and appropriate [19]. The questionnaire was pilot-tested with a small sample of 13–17-year-old school children to confirm that the intent of each of the items was clear to the target population and the questionnaire was well understood [19].

Study participants

The 2014 Bangladesh GSHS participants were selected using a standardised two-stage cluster sampling design to select schools at the first stage and randomly selected classes within the sampled schools at the second stage. All students in the selected classes were invited to participate and included in the sampling frame.

Ethics approval

Only adolescents and their parents who provided written/verbal consent participated. The GSHS surveys received ethics approval from both a national government administration and an institutional review board or ethics committee. As the current study used retrospective publicly available data, we did not require ethics approval from any Institutional Ethics Review Committee for this secondary analysis.

Measurements

Survey participants were asked about cigarette smoking and alcohol consumption with the following questions, respectively: "During the past 30 days, on how many days did you smoke cigarettes?" and "During the past 30 days, on how many days did you have at least one drink containing alcohol?" with the response options for both items being 0, 1 or 2, 3 to 5, 6 to 9, 10 to 19, 20 to 29, or all 30 days. In the questionnaire, "one drink" corresponded to either one glass of wine, one bottle of beer, one small glass of liquor, or one mixed drink. Fruit and vegetable consumption was assessed with the questions: "During the past 30 days, how many times per day did you usually eat fruit, such as bananas, guava, mango, pineapple, apples, oranges, jackfruit, boroi, or amra?" and "During the past 30 days, how many times per day did you usually eat vegetables, such as potatoes, potol, cauliflower, cabbage, beans, brinjal, or chichinga?" The response options were "I did not eat fruit during the past 30 days"; <1, 1, 2, 3, 4, or ≥5 times/day. Physical activity was assessed with a single item asking about the number of days on the past 7-day recall participants were physically active for a total of at least 60 min per day. Sedentary behaviour was measured with a single item "How much time do you spend during a typical or usual day sitting and watching television, playing computer games, talking with friends, or doing other sitting activities?" with the response options <1, 1 to 2, 3 to 4, 5 to 6, 7 to 8, or >8 h/day. Trained survey staffs measured height and weight of the participants.

Definition of behavioural risk factors of CVDs

Current cigarette smoking was defined as smoking at least one day in the past 30 days [20] and current alcohol as having at least one drink in the past 30 days [6]. Low or inadequate fruit and vegetable intake was defined as having fruit and vegetables less than two and three times per day during the past 30 days, respectively [21]. Physical inactivity was defined as not doing at least 60 min of activity on all seven days of the week [22]. High sedentary behaviour was defined as ≥3 h/day of sitting-time outside of school [23,24]. BMI (weight(kg)/height(m)^2) was categorised as underweight (BMI < −2SD), overweight (BMI> +1SD), and obese (BMI> +2SD), relative to median BMI, by age and sex based on the WHO Child Growth Standards [25]. Each of the risk behaviours was coded as a dichotomous variable (Yes=1; No=0) before summing them to generate a risk factor index, ranging from 0 to 6 (0=no risk factor, 6=all risk factors).

Statistical analysis

Weighted proportions of adolescents with single and multiple risk factors and their 95% confidence interval (95% CI) were estimated by taking into account the weighting factor that was applied to each student record to adjust for non-response and the varying probability of selection. Behavioural risk factors were studied for possible clustering through examining ratios of observed (O) and expected (E) prevalence of one or more simultaneously occurring

Table 1
Prevalence of single behavioural risk factors in Bangladeshi adolescents aged 11–17 years, stratified by sex, Global School-based Student Health Survey, Bangladesh, 2014.

Risk factors (n)	Total, prevalence (95% CI)	Males, prevalence (95% CI)	Females, prevalence (95% CI)	p-value[#]
Low fruit & vegetable (2,919)	86.9 (85.3 – 88.4)	87.2 (84.8 – 89.2)	86.4 (84.6 – 88.1)	0.022
Physical inactivity (2,904)	58.6 (56.1 – 61.1)	58.2 (54.7 – 61.7)	59.4 (56.6 – 62.1)	<0.001
High sedentary behaviour (2,872)	15.2 (13.4 – 17.2)	16.9 (14.4 – 19.8)	12.0 (10.2 – 14.0)	<0.001
Overweight/obesity (2,703)	9.0 (7.6 – 10.7)	9.9 (7.8 – 12.4)	7.4 (6.1 – 9.1)	0.25
Smoking (2,952)	7.6 (6.4 – 9.1)	11.0 (9.1 – 13.2)	1.4 (0.8 – 2.3)	<0.001
Alcohol intake (2,956)	1.7 (1.1 – 2.6)	2.5 (1.6 – 3.9)	0.1 (0.04 – 0.44)	<0.001

Abbreviations: CI=confidence intervals.
[#] represents significance of sex difference based on Chi-square test.

Table 2
Clustering pattern of multiple behavioural risk factors in Bangladeshi adolescents aged 11–17 years, stratified by sex, Global School-based Student Health Survey, Bangladesh, 2014.

Risk factors	Smoking	Alcohol intake	Physical inactivity	High SB	Low fruit & vegetable	Overweight/ obesity	Males			Females		
							O (%)	E (%)	O/E (95% CI)	O (%)	E (%)	O/E (95% CI)
0	–	–	–	–	–	–	2.9	3.5	0.8 (0.5 – 1.4)	10.7	4.4	2.4 (2.1 – 2.8)
1	–	–	–	–	–	+	0.4	0.4	1.0 (0.3 – 4.0)	0.3	0.4	0.8 (0.3 – 1.9)
1	–	–	–	–	+	–	21.4	23.6	0.9 (0.8 – 1.1)	22.9	28.2	0.8 (0.7 – 0.9)
1	–	–	–	+	–	–	0.5	0.7	0.8 (0.2 – 2.8)	0.7	0.6	1.2 (0.6 – 2.4)
1	–	–	+	–	–	–	2.6	4.8	0.5 (0.3 – 0.9)	2.0	6.5	0.3 (0.2 – 0.5)
1	+	–	–	–	–	–	4.1	0.4	9.4 (7.7 – 11.5)	0.3	0.1	5.6 (3.2 – 9.8)
2	–	–	–	–	+	+	1.9	2.6	0.7 (0.4 – 1.3)	2.5	2.3	1.1 (0.7 – 1.6)
2	–	–	–	+	+	–	5.7	4.8	1.2 (0.9 – 1.6)	4.2	3.8	1.1 (0.8 – 1.5)
2	–	–	+	–	–	+	0.4	0.5	0.7 (0.2 – 2.5)	0.2	0.5	0.3 (0.1 – 1.1)
2	–	–	+	–	+	–	36.1	28.0	1.3 (1.2 – 1.4)	44.5	37.1	1.2 (1.1 – 1.3)
2	–	–	+	+	–	–	0.5	1.0	0.5 (0.2 – 1.5)	0.1	0.9	0.1 (0.0 – 0.4)
2	+	–	–	–	+	–	1.5	2.9	0.5 (0.3 – 1.0)	0.5	0.4	1.2 (0.4 – 3.2)
2	+	–	–	+	–	–	0.2	0.1	2.6 (0.5 – 13.7)			
3	–	–	–	+	+	+	1.3	0.5	2.5 (1.3 – 4.9)	0.3	0.3	1.1 (0.4 – 3.0)
3	–	–	+	–	+	+	5.2	3.6	1.4 (1.1 – 2.0)	3.5	3.3	1.1 (0.8 – 1.5)
3	–	–	+	+	+	–	7.2	6.7	1.1 (0.8 – 1.4)	6.6	5.6	1.2 (0.9 – 1.5)
3	–	+	–	+	+	–	0.1	0.1	0.6 (0.2 – 2.6)			
3	–	+	+	–	+	–	0.3	0.8	0.3 (0.1 – 1.5)			
3	+	–	–	+	+	–	0.4	0.6	0.7 (0.2 – 2.5)			
3	+	–	+	–	+	–	4.1	4.1	1.0 (0.7 – 1.5)	0.4	0.6	0.7 (0.2 – 2.2)
4	–	–	+	+	+	+	1.0	0.7	1.4 (0.6 – 3.4)	0.2	0.5	0.5 (0.2 – 1.1)
4	+	+	+	–	+	–	0.3	0.1	2.4 (0.4 – 12.9)			

Note: There was only one case in each of the 11 combinations and as such, they were not presented in the table.
(+) sign indicates presence of a risk factor and (-) sign indicates absence of a risk factor.
Abbreviations: SB=sedentary behaviour, *O*=observed prevalence, *E*=expected prevalence, *O*/*E*=observed vs. expected prevalence ratio, CI=confidence intervals.

risk behaviours. The expected proportion was calculated by multiplying the individual probabilities of each risk factor based on their occurrence in the study sample for male adolescents ("males" hereafter) and female adolescents ("females" hereafter) separately. An observed-expected ratio (O/E) greater than one (i.e., the observed proportion exceeds its expected proportion), suggests the presence of a clustering [26].

Poisson regression was used to examine the inter-relationships among the six risk behaviours. Prevalence odds ratios (ORs) and their 95% CI were computed to examine the associations between pairs of risk behaviours, adjusted for age, sex, and hunger status (as a proxy of socioeconomic status). If the 95% CI of the OR did not include 1, it suggested a clustering between the two behavioural risk factors. Analyses were performed separately for males and females as the prevalence of the risk behaviours were substantially different across sex. All statistical analyses were performed using Stata version 14.0 SE (StataCorp, College Station, Texas, USA).

Results

Of the 2,989 survey participants, 11 were excluded from the analyses due to missing information on sex and/or age. The mean age of the analytical sample ($n = 2,978$) was 14.2 (SD: 0.99; range: 11–17) years, and 60% were females.

The most common single behavioural risk factor was low fruit and vegetable intake, with a prevalence of 86.9% (87.2% for males and 86.4% for females) (Table 1). Physical inactivity was the second most common risk behaviour (58.6%; 58.2% for males and 59.4% for females), followed by high sedentary behaviour (15.2%; 16.9% for males and 12.0% for females). Compared to females, males were more likely to report low fruit and vegetable intake ($p = 0.022$), high sedentary behaviour ($p<0.001$), smoking ($p<0.001$), and alcohol intake ($p<0.001$). Females were more likely than males to report physical inactivity ($p<0.001$) (Table 1). Overall, 17.6% of adolescents had three or more risk factors. The analysis demonstrated significant sex differences with 21.3% of males, compared to 11.2% of females, reporting three or more risk behaviours ($p<0.001$) (Fig. 1). About 32% of males reported one or no risk behaviour compared to 37% of the females.

Clustering pattern of possible combinations of the six risk behaviours, stratified by sex, are presented in Table 2. Of the 64 possible combinations from six risk behaviours, 31 combinations did not have any data, and therefore, were excluded from the analysis. Observed prevalence of physical inactivity and low fruit and vegetable intake was higher than could have been expected in both sexes if there was no clustering, with O/E ratio being 1.3 (95% CI 1.2–1.4) for males and 1.2 (1.2–1.3) for females. The analysis also demonstrated clustering of high sedentary behaviour, low fruit and vegetable, and overweight/obesity (2.5 [1.3–4.9]); and physical inactivity, low fruit and vegetable, and overweight/obesity (1.4 [1.1–2.0]) for males. However, there was no evidence of clustering of three or more behavioural risk factors for females.

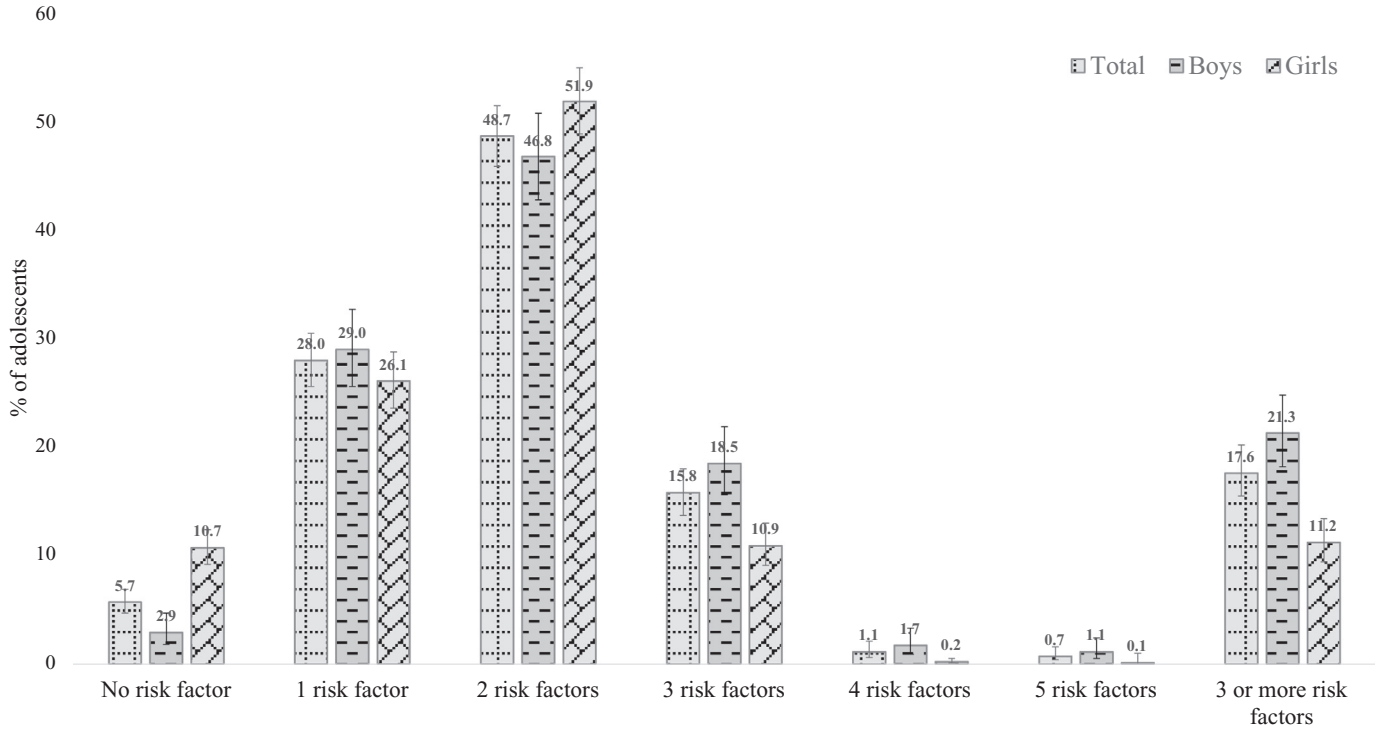

Fig. 1. Distribution of total number of behavioural risk factors in Bangladeshi adolescents aged 11–17 years, stratified by sex, Global School-based Student Health Survey, Bangladesh, 2014.

Table 3
Prevalence odds ratio (95% CI)[#] matrix of multiple behavioural risk factors in Bangladeshi adolescents aged 11–17 years, stratified by sex, Global School-based Student Health Survey, Bangladesh, 2014.

	Low fruit & vegetable	Physical inactivity	High SB	Overweight/obesity	Smoking	Alcohol intake
Overall						
Low fruit & vegetable	1					
Physical inactivity	1.23 (1.18–1.28)	1				
High SB	1.05 (1.02–1.13)	0.97 (0.86–1.11)	1			
Overweight/obesity	1.04 (0.98–1.10)	1.04 (0.90–1.20)	1.21 (0.79–1.85)	1		
Smoking	0.70 (0.62–0.79)	0.87 (0.71–1.07)	0.94 (0.56–1.60)	0.29 (0.18–1.07)	1	
Alcohol intake[§]	1.01 (0.85–1.19)	1.53 (1.33–1.79)	4.53 (3.18–6.48)	0.49 (0.17–3.25)	5.63 (3.72–9.82)	1
Males						
Low fruit & vegetable	1					
Physical inactivity	1.18 (1.11–1.25)	1				
High SB	1.06 (0.99–1.13)	0.97 (0.83–1.15)	1			
Overweight/obesity	1.03 (0.95–1.12)	1.04 (0.87–1.26)	1.32 (0.81–2.15)	1		
Smoking	0.69 (0.61–0.79)	0.92 (0.74–1.14)	0.99 (0.57–1.73)	0.15 (0.02–1.06)	1	
Alcohol intake[§]	1.01 (0.85–1.20)	1.56 (1.32–1.84)	4.59 (3.20–6.56)	0.51 (0.08–3.41)	6.42 (3.56–11.57)	1
Females						
Low fruit & vegetable	1					
Physical inactivity	1.32 (1.25–1.38)	1				
High SB	1.09 (1.04–1.14)	0.93 (0.79–1.10)	1			
Overweight/obesity	1.08 (1.02–1.16)	1.05 (0.87–1.26)	0.85 (0.44–1.64)	1		
Smoking	0.95 (0.79–1.14)	0.84 (0.49–1.44)	0.85 (0.13–5.48)	3.18 (0.89–11.39)	1	
Alcohol intake[§]	1.22 (1.08–1.38)	0.70 (0.15–3.22)	Not estimated*	Not estimated*	Not estimated*	1

Abbreviations: CI=confidence intervals, SB=sedentary behaviour.
[#] adjusted for age and hunger; sex was included in the model for the overall estimates; [§]alcohol consumption was reported by only 1.7% of the participants and as such, they offered unstable estimates of ORs; *due to small sample size.

Inter-relationships among the six risk behaviours by sex, adjusted for age and hunger status, using Poisson regression are presented in Table 3. Four of the 15 pairs were significantly and positively associated for females. For males, five out of 15 pairs were significantly associated with four being positively and one being negatively associated. Low fruit and vegetable intake was positively associated with physical inactivity for both females (OR 1.32 [95% CI 1.25–1.38]) and males (1.18 [1.11–1.25]). For females, low fruit and vegetable intake was positively associated with high sedentary behaviour (1.09 [1.04–1.14]) and being overweight/obese (1.08 [1.02–1.16]). For males, alcohol intake was positively associated with physical inactivity (1.56 [1.32–1.84]), high sedentary behaviour (4.59 [3.20–6.56]), and smoking (6.42 [3.56–11.57]); however, low fruit and vegetable intake was inversely associated with smoking (0.69 [0.61–0.79]). Although physical inactivity was positively associated with overweight/obesity, they were not statistically significant.

Discussion

To our knowledge, this is the first study to evaluate the clustering patterns of CVD behavioural risk factors among adolescents in

Bangladesh. Using nationally representative data, the current study identifies that low fruit and vegetable intake and physical inactivity were clustered for both females and males. Low fruit and vegetable intake, and overweight/obesity tended to cluster with physical inactivity and high sedentary behaviour for males. Our results are in line with previous studies in other South Asian countries including India [27], Nepal [28], and Pakistan [29], and other countries such as Brazil [30], South Korea [8], and Saudi Arabia [31], which showed clustering of risk factors in adolescents. Given that the presence of multiple CVD risk factors in young people could lead to high blood pressure, cardio-metabolic diseases, and progression of atherosclerosis and cardiovascular complications in later life [11], the findings of the current study signify the importance of addressing multiple risk behaviours simultaneously at an early age to avoid possible catastrophic health consequences in adult life.

We found that CVD risk factors such as low fruit and vegetable intake and physical inactivity were present in more than half of the study population (87% and 59%, respectively). Among adolescents in other South Asian countries [27–29], the prevalence of low fruit and vegetable intake ranged from 65% in India to 95% in Nepal, and the prevalence of physical inactivity ranged from 52% in India to 85% in Nepal. A more concerning observation was the presence of multiple CVD behavioural risk factors where about two-thirds of the adolescents had two or more risk factors (68% in males and 63% in females). This prevalence of two or more risk factors was lower than the prevalence reported among adolescents in the neighbouring South Asian countries such as India (91%) [27], Nepal (83%) [28], and Pakistan (>80%) [29]; slightly lower than the prevalence of 74–76% reported in Brazilian studies [30,32]; and comparable to that reported in a Canadian study (65%) [7]. Our analysis shows considerable gender differences in all behavioural risk factors but overweight/obesity, which are similar to what has been reported in a recent study in Nepal [28]. High sedentary behaviour was more common among males than females. Smoking and alcohol intake were considerably higher among males than their female counterparts were, which is consistent with current literature [6]. Thus, any prevention program needs to be gender-specific in order to target specific groups to combat CVDs.

Our study reports a high prevalence of multiple CVD risk factors and their co-occurrence among adolescents. The analysis shows that low fruit and vegetable intake was positively associated with physical inactivity for both males and females, while smoking was positively associated with alcohol consumption in males, but not for females. As many of the behaviours acquired during adolescence tend to remain in adulthood [6], identifying these modifiable risk factors earlier in life has the potential to reduce the propensity to CVDs in later life. This study underscores the need for raising awareness among adolescents about the importance of avoiding such behaviours and the benefits of maintaining an active lifestyle and a healthy diet. This initiative should be complemented by appropriate evidence-based policies and strategies to scale-up the campaign against CVD risk factors among the country's adolescents.

The WHO Global Action Plan for the Prevention and Control of Non-Communicable Diseases 2013–2020 has proposed a target for the Member States to "Halt the rise in diabetes and obesity" globally with a special focus on childhood obesity, and to restrict the marketing of food and beverage products, which are high in saturated and trans fats, as well as added sugars and sodium [33]. It has been argued that to address childhood obesity effectively, multiple approaches implanted in tandem are required instead of targeting a single intervention [34]. Evidence from Europe shows that banning TV advertisement of junk-food aimed at children, taxation on unhealthy foods, and substituting healthier foods at school helped to reduce obesity rates among children and adolescents in the region [34]. Policies to make fresh fruits and vegetables more accessible to adolescents, restricting the promotion and availability of energy-dense foods and increasing tax for sugar-sweetened drinks have shown to reduce consumption of unhealthy diet in many countries such as the UK and Australia [35].

Youth smoking rates have decreased considerably in the USA and many European countries in response to different tobacco control legislation, comprehensive smoke-free legislation and regulatory interventions [36,37]. Increased taxation on tobacco products, implementation of clean indoor-air policies at schools, parks, entertainment venues, and other public facilities, restriction on youth access to tobacco, and advertising and marketing restrictions on tobacco have been shown to be effective in reducing the use of tobacco, exposure to tobacco smoke, and nicotine dependency among adolescents in these countries [36,37].

Available evidence suggests that a more active lifestyle can be promoted by reducing sedentary behaviour, encouraging spontaneous play, promoting everyday activities and sports, emphasising the importance of physical education class, increasing the variety of activities, and encouraging hobbies [38]. School-based interventions targeting physical activity and sedentary behaviour have demonstrated promising results in many studies [39]. It has been argued that school-based initiatives should involve and ensure quality physical education, opportunities for physical activity before and after school, walking and bicycling to and from school, competitive and non-competitive sport activities before and after school, and involvement of the staff members, and share school facilities before and after school with family and community engagement [40]. Family-based interventions also represent a potentially valuable route to increasing physical activity in children and adolescents [41], while the community setting could be a promising avenue for the promotion of physical activity [42].

Our results have important implications for public health practice and policy strategies for early prevention and management of CVDs in Bangladesh. Within the current healthcare system and infrastructure of Bangladesh, the government and private sectors primarily provide clinical care and treatment services at the tertiary level with limited focus on the preventive aspects of CVDs [43]. In 2011, Bangladesh adopted a national children policy [44] to promote physical and psychosocial wellbeing of children (aged <18 years) with a particular focus on proper nutrition and opportunities for healthy recreation such as sports participation. The recent Bangladesh Health, Nutrition and Population Strategic Investment Plan, 2016–21 [43] has introduced 'lifestyle approach' to reduce ramifications of rapidly increasing chronic NCDs and set priorities for early detection and control of NCDs (including CVDs) and their risk factors, especially among youth. This plan is, however, not complemented by relevant and specific details about its implementation, and as such, it lacks the capacity to improve NCD care in a more integrated manner.

Realising the need for actions from several sectors including finance, transport, education, agriculture, and trade, Bangladesh has recently adopted a Multi-sectoral Action Plan for Prevention and Control of Non-Communicable Disease, 2018–2025 specifically to tackle the silent epidemic of NCDs [45]. The three-year operational plan of this initiative includes, among others, promotion of health behaviours (e.g., increase physical activity, reduce tobacco and alcohol use), healthy diet (e.g., reduce salt consumption, increase fruit and vegetable intake, awareness against junk-food and soft drinks), and healthy settings through healthy cities and healthy schools approach (e.g., making walkable urban environments such as pedestrian sidewalks, parks, control of smoking in public places). This multi-sectoral action plan is expected to bring all stakeholders, including the Prime Minister's Office on the same platform in order to deliver an efficient and successful NCD prevention and control program in Bangladesh which is encouraging. However, this plan must be supplemented by evidence-

based pragmatic strategies with adequate resources, including the required budgetary allocation. Given the limited share of GDP invested in health (<1% by public sector) in Bangladesh, addressing multiple risk behaviours at an early stage of life has the potential to prevent and control future CVDs, which can, in fact, be more of a cost-saving strategy than a costly initiative of tertiary prevention [46].

The main strength of this study is the use of a large nationally representative sample of adolescents in Bangladesh. The weighted analysis of this study adjusted the results for non-response of schools and students, and any skewness in the distribution of the population by sex and grade, which has made the presented results generalisable. The other strength of the study is the evaluation of six main behavioural risk factors in adolescents, in contrast to most other studies that examined isolated risk behaviours. In addition to the common ones, this study included sitting-time in the analysis, which can contribute to the understanding of sedentary behaviours in conjunction with other behavioural risk factors of CVDs. Study limitations include the self-reported behavioural risk factor assessment where some participants may have misreported their adverse behaviour either out of embarrassment or to provide a socially desirable response. However, there is little reason to believe that many adolescents would systematically misreport their behaviours, which could potentially bias our findings. Since a third of the participants had one or no risk factor out of six, the prevalence of majority of the higher-order combinations were very low, which has made it difficult to interpret many of the O/E ratios. The criteria and cut-off used to make the risk behaviours binary may introduce some bias in the estimates. The analysis could not include any biological risk factors of CVDs (e.g., cholesterol, hypertension) as they were not collected in the GSHS. Despite these limitations, the present study is the first of its kind to provide insights into clustering patterns of CVD risk behaviours among adolescents and fills a gap in the literature on CVD risk behaviours of adolescents in resource-poor settings.

In conclusion, our findings show the pervasive burden of behavioural risk factors of CVDs among adolescents in Bangladesh, which has important implications for policy and programmes. The CVD behavioural risk factors in this study tended to co-occur more often than expected among adolescents, which may challenge the use of most traditional health promotion strategies that address single risk factors. Primary prevention programs should be started during the early stage of life to target a range of CVD behavioural risk factors rather than focussing on single risk factors. In particular, gender-specific intervention programs may be required to target adolescents who are at a greater risk of engaging in multiple risk behaviours. Long-term prospective studies with objective measures of cardiovascular and behavioural risk factors in adolescents are needed in Bangladesh to track and better understand the clustering of adolescents' risk behaviours and their determinants.

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