ORIGINAL ARTICLE

Stunting and its determinants among adolescents in four schools of Bangalore city: Height for age- a vital metric for nutritional assessment

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Abstract

Background: National Family Health Surveys in India have not included nutritional status of the crucial age group of 10-14 years, when pubertal growth spurt typically occurs. BMI-for-age is commonly used to assess adolescent nutritional status which may misclassify stunted adolescents as normal or overweight. **Objectives:** To estimate prevalence and determinants of stunting among adolescents (10 to 19 years) in Bangalore city and to estimate the proportion of adolescents who are stunted, but otherwise assessed as normal or overweight using BMI-for-age. **Methods:** Cross sectional study conducted in four schools of Bangalore city using a self-administered questionnaire to capture socio-demographic details, dietary patterns and physical activity. WHO Anthroplus software was used to classify nutritional status based on height-for-age and BMI-for-age. Multiple logistic regression analysis was done to calculate adjusted odds ratios of independent co-variates associated with stunting. **Results:** Overall prevalence of stunting was 14% (95%CI:11.5-16.5%); 14.3% among females (95%CI:10.7-17.9%) and 13.6% among males (95%CI: 10.2-17.0%). Determinants of stunting were late adolescence [AOR=1.90(1.24-2.90),*P*=0.03], lower socio-economic class [AOR=2.75(1.39-5.41),*P*=0.03] and not taking weekly iron and folic acid supplements [AOR=2.78(1.48-5.21),*P*=0.001] Four of every five stunted children (81%) were classified as normal/ overweight/ obese using BMI-for-age. **Conclusion:** Stunting is a problem among urban adolescents in Bangalore. Height-for-age is a vital metric for assessing nutritional status of adolescents along with other metrics. We recommend strengthening of weekly iron and folic acid supplementation in schools and culturally specific targeted nutritional interventions for adolescents from economically weaker sections of society using a multi-sectoral and participatory approach.

Keywords

Stunting; Adolescent Nutrition; Nutritional Status; Iron Folic Acid Supplements; Schools

Introduction

Adolescence is a crucial period of growth from the ages of 10 to 19 years.(1) Nutrition needs are the highest during adolescence as this period is characterized by rapid growth,(2) when nearly 45-50% of skeletal growth and 20-25% of adult height is attained.(3) Among adolescents aged 10-19 years of age, short stature or stunting, is defined as height-for-age below -2 z-score by the World Health Organization (WHO) adolescent standard growth references.(4) Indicative of chronic undernutrition, stunting also reflects infection, and environmental stress that has occurred in the foetal period, continued through childhood and up to adolescence.(5) Stunting is perpetuated by an intergenerational cycle of growth failure, with a trajectory of low nutritional status in adolescence and young adulthood, maternal malnutrition in pregnancy, and low weight and length at birth.(6) Consequences of stunting in adolescence includes adverse effect on intellectual development, school attendance, academic performance, social skills, reduced work capacity lower productivity and earnings.(7)

India is home to the largest adolescent population in the world with 253 million adolescents, that is one in every five Indians.(8) In spite of growth in economy and advancement in technology, India continues to suffer from unacceptable levels of malnutrition. The prevalence of stunting among 15-19 years as per the National Family Health Survey (NFHS-4) is 34.1%, higher than the previous NFHS-3, where 29.1% were stunted.(9) However, NFHS surveys do not include data on the crucial age of early adolescence (10-14 years), a time when puberty begins and critical growth spurt occurs,(3)and a period where interventions to reduce stunting could prove of immense value.

Body Mass Index (BMI)-for-age estimates have long been favored as a reporting metric for adolescent nutritional status, however, bodyweight tends to be low in many low and middle-income countries and coupled with low stature, may erroneously classify nutritional status as normal if based on BMI alone, or adolescents with normal body weight and short stature may get classified as overweight or obese.(5) With more than a third of India's population residing in urban areas,(10) there is worrying lack of published literature in India on stunting in urban areas, especially during the entire period of adolescence, that is 10-19 years. There is also paucity of data in the Indian subcontinent examining the relation between stunting and unhealthy diet and physical activity. The few studies that have been done, focus more on urban slums or adolescent girls.

Aims & Objectives

1. To estimate the prevalence of stunting among adolescents aged 10 to 19 years in Bangalore city
2. To identify the determinants of stunting in this population
3. To estimate the proportion of adolescents who are stunted, but otherwise assessed as normal or overweight using BMI-for-age.

Material & Methods

Study Design: This was a cross sectional study. **Study Area**: The study was conducted in schools of one selected ward of Bangalore city. This ward was chosen as it had four different types of schools; two government schools, one private aided, and one private school, and was located close to the medical college urban field practice area. The data was collected over a three month period and data analysis done over a two month period in 2019. **Study Population:** All adolescents enrolled in these schools aged 10-19 years were included in the sampling frame of this study. **Sample size calculation:** Considering a confidence level of 95%, and based on NFHS-4 prevalence of 34.1% stunting among adolescents,(9) with 5% margin of error, the sample size for our study was estimated to be 345. The school authorities requested the research team to include all the adolescents enrolled in the school to determine their nutritional status. We therefore included all students meeting the inclusion criteria, in the study. **Inclusion criteria:** Students aged 10-19 years, students who had parental consent and gave assent. **Exclusion criteria:** If any students were absent at two consecutive visits by the investigators, they were excluded from the study. **Data Collection and Study Tools:** Each participant completed a pre-tested, self-administered, structured questionnaire that recorded socio-demographic and economic details, their diet and physical activity, including socio-economic classification by Modified BG Prasad Classification.(11) Two experts in the field of adolescent health validated the questionnaire and it was pilot-tested prior to use. The questionnaire was made available in both English and the local language Kannada. Height and weight were recorded using standard tools and procedures. WHO Anthroplus software (12) was used to classify height and BMI as per age of the subjects according to z scores for 5-19 years. Using WHO height-for-age z-scores, subjects were classified as Tall: >2, normal: -2 to 2, stunting: < -2 to -3, severe stunting: < -3.(13) Using WHO BMI-for-age z-scores, subjects were classified as obese: >2, overweight: >1 to 2, normal: -2 to 1, thinness: < -2 to -3, severe thinness: < -3.(13) **Operational Definitions:** Early Adolescence: age of 10-14 years, Late Adolescence: age of 15-19 years.(14) Adequate intake of fruits and vegetables: 4 to 5 servings of fruits and vegetables a day, at 80g each serving.(15) Adequate physical activity: moderate to vigorous intensity exercise of ≥60 minutes at least five days of the week like brisk walking, running, jogging, cycling, swimming, playing outdoor sports or using the gym.(16) **Ethical Considerations:** Permission for this research study was obtained from the Block Education Officer and the school managements, and Institutional Ethics Committee ethics approval was obtained. **Statistical Analysis**: Data was analyzed using IBM Standard Package Statistical Software (v.20). Variables were described with frequencies, proportions, mean, standard deviation, median and inter-quartile range. Prevalence of outcome variable (stunting) was described as a proportion with 95% confidence intervals (CI). Association of stunting with various independent co-variates (socio-demographic and economic factors, dietary practices and physical activity) was done using Chi-square test. Multiple logistic regression model was generated with variables having P value <0.2, using 'forward step-wise selection method'. For all analyses, P <0.05 was taken to be statistically significant.

Results

The total number of adolescents who participated in the study was 752, of whom 451(60%) were in early adolescence and 301(40%) in late adolescence with nearly equal number of male (50.8%) and female (49.2%) adolescents and equal number of government (49.3%) and private (50.7%) school students. Most belonged to

lower socio-economic class (46.3%), and 7.7% belonged to backward caste.

Prevalence of Stunting: Among the adolescents in the study, 14% were stunted (95% CI: 11.5-16.5%), this included 1.6% who were severely stunted [Table 1]. The prevalence of stunting among males was 13.6% (95% CI: 10.2-17.0%) and 14.3% (95% CI: 10.7-17.9%) among females. The prevalence of stunting among the early adolescent group was found to be 10.4% (95% CI:7.6-13.2%) and among late adolescents it was 19.3% (95% CI: 14.8-23.8%). A large majority (81%) of the stunted children were classified as normal/ overweight/ obese by BMI-for-age. [Table 2].

Determinants of stunting: Boys were found to have highest proportion of stunting at the ages of 17-19 years and girls at 15-19 years. [Table 3]. Stunting was significantly higher among late adolescents (P<0.001), those studying in government schools (P<0.001), those from lower socio-economic class (P=0.002) and belonging to backward caste (P=0.038). There was no significant difference in stunting between male and female adolescents [Table 4]. Adequate daily intake of fruits and vegetables was reported by only 43.9% of the subjects. Dietary factors like consuming vegetarian or vegan diet, skipping meals, consuming sugary fizz drinks, packaged snacks, bakery items and fast foods like pizza and burger at least once a week were not associated with stunting [Table 5]. Stunting was significantly associated with lack of physical activity, like not participating in sports (P=0.020) and not having adequate physical activity (P=0.026). Stunting was not associated with mode of transport to school or duration of sleep in a day [Table 6].

After regression analysis, late adolescents were found to have twice the risk of stunting as compared to early adolescents [AOR=1.90 (1.24-2.90), P=0.03]. Adolescents belonging to lower socio-economic class had nearly three times greater risk of stunting as compared to those of upper class. [AOR=2.75 (1.39-5.41), P=0.03]. Those who did not take weekly supplements of iron and folic acid had nearly three times higher chance of stunting than those who took these micronutrient supplements. [AOR=2.78 (1.48-5.21), P=0.001] [Table 7].

Discussion

Among the adolescents enrolled in four schools in a ward of Bangalore city, we found that one in every seven adolescents were stunted, which was much lower than a study in rural West Bengal which found that over half (54%) of the adolescents aged 10-17 years were stunted.(17)This may be explained by the higher proportion of adolescents from low income families in the West Bengal study. A study which analysed the data from NFHS-4, looking specifically at the effect of socio-economic factors on childhood malnutrition in 640 districts of India,(18) found that the southern states had lower proportion of undernutrition and stunting as compared to eastern and northern states of India primarily due to difference in income levels. A study in Yemen among children and adolescents aged 5-19 years, also found that those from poor families had twice the chance of being stunted.(19) Stunting in adolescence is a result of poor nutrition, infection, and environmental factors that play a role right from the initial fetal period and through young adulthood,(5) and most of these factors are linked to low socio-economic status. In our study too, it was seen that adolescents from lower socio-economic class were significantly more likely to be stunted than those from middle or upper classes. Our study findings resonate with the NFHS-4 findings for our state of Karnataka which estimates 26.6% stunting in the age group of 15-19 years.(9) We found that one in every five late adolescents were stunted. Late adolescents in our study had double the risk of stunting as compared to early adolescents. A survey in two Indian states (Uttar Pradesh and Bihar) found a similar risk.(20) This phenomenon of “unmasking” of stunting in the late adolescent period has been described by Soliman et al who explained how undernutrition delays puberty, and results in a later age, lower velocity and shorter duration of linear growth.(3)

The present study revealed no significant difference in stunting between boys and girls, which was similarly found by the National Nutritional Monitoring Bureau (NNMB) across nine Indian states in 2006 (21) and the pan-Indian NFHS-4 survey in 2015-16.(9) In our study, adolescents who did not take weekly supplements of iron and folic acid (IFA) had nearly three times higher chance of stunting than those who took these micronutrient supplements. Studies have also shown that many adolescents do not meet their recommended daily intake of micronutrients due to lack of fruits and vegetables, thereby placing them at risk for micronutrient deficiencies. (22,23) Our study too found that less than half of the adolescents had adequate daily intake of fruits and vegetables, though this was not significantly associated with stunting. In a systematic review of dietary practices among adolescent girls in low and middle income countries, it was found that adequate fruit and vegetable intake was lowest in South Asia, with recommended daily servings of fruits and vegetables not being consumed by 97% and 90% of the adolescents, respectively.(24)

Our study has revealed the importance of the weekly IFA supplementation programme for school-going adolescents, an evidence-based strategy by the Ministry of Health and Family Welfare, Government of India.(25) Aimed to reduce anaemia among adolescents, this intervention can also help prevent stunting. The effect of iron deficiency anaemia on linear growth has been explained by novel endocrine pathways. Anemia causes hypoxia in hepatocytes, which results in poor hepatic synthesis of transferrin and insulin-like growth factor-1 (IGF-1), which are critical for growth. Besides being an

iron-carrier protein, transferrin also binds IGF-1. Anaemia therefore results in poor IGF-1-induced cell proliferation and decreased growth.(26) A clinical trial in children has found that iron therapy increased circulating IGF-1 significantly, along with acceleration of growth velocity and increased height.(27)

BMI-for-age is the most common chosen metric when reporting nutritional status of adolescents and is often used in isolation as a single metric. But since BMI is determined by dividing the weight in kilograms by the height in metres squared, higher BMI may exist in subjects who have suboptimal linear growth,(5) thereby misclassifying a subject as being well-nourished, when in fact the child is under-nourished (stunted). Four out of every five adolescents with stunting in our study, were classified as either normal or overweight when we used BMI-for-age. The denominator in the calculation of BMI is height squared, therefore a reduction in height automatically results in an increase in BMI. Furthermore, in a study among children in rural South Africa, it was seen that the prevalence of stunting was associated with overweight and obesity. The authors suggest that this finding might be due to the poor quality of the diet which is heavily carbohydrate-based and low in animal protein, fats and micronutrients. The lack of animal protein in the diet has possibly inhibited linear growth, while high proportion of carbohydrates leads to fat deposition and obesity.(28) This paradoxical finding of overweight and obesity co-existing with stunting among adolescents indicates a direction for future research, exploring the link between diet and stunting in the presence of obesity. In the meantime, we can summarize from this finding that BMI-for-age alone should not be used to determine nutritional status, and that height-for-age is vital for growth monitoring and assessment of nutritional status of adolescents, and should be used in tandem with BMI-for-age.

Stunting indicates chronic under-nutrition and holds a mirror up to society. It is a reflection of economic disparity, lack of food security, education and basic amenities like water, sanitation and hygiene.(29) Therefore addressing the problem of stunting requires an inter-sectoral approach. The scope of interventions need to be broadened beyond the pre-school age. Efforts should focus on the economically weak. While the mid-day meal program and weekly iron and folic acid supplementation in government schools aim to provide the much needed extra calories and micronutrients, we need to strengthen these strategies and have a more participatory approach involving adolescents, teachers and parents, to make targeted nutrition-interventions more culturally specific.

Adoption studies provide evidence showing that catch-up growth is possible during adolescence.(30,31) Adolescence may therefore be a second window of opportunity for interventions to address stunting, an opportunity that should not be missed.

Conclusion

Our study found that one in every seven adolescents were stunted. The prevalence of stunting among early adolescents was 10.4% and nearly doubled among late adolescents (19.3%). Determinants of stunting included lower socio-economic class and not taking weekly IFA supplements. A large proportion (81%) of the stunted children were classified as normal/ overweight/ obese using BMI-for-age, indicating that height-for-age is a vital metric for assessment of nutritional status of adolescents along with other metrics. We recommend strengthening of weekly iron and folic acid supplementation in schools and culturally specific targeted nutritional interventions for adolescents from economically weaker sections of society using a multi-sectoral and participatory approach.

Recommendation

Height-for-age is a vital metric for growth monitoring and assessment of nutritional status of adolescents and as a standard policy, should be used in tandem with BMI-for-age. This should be emphasized to health personnel involved in health appraisals at schools, pre-university and across adolescent health clinics. We found that stunting was significantly higher among those who did not take weekly IFA supplements and this adds to the body of evidence that weekly IFA should be continued in schools as it promotes linear growth among adolescents.

Limitation of the study

Due to resource constraints, we could not gather data on the calorie, protein and micronutrient intake of the study subjects, which would have been a value-addition to our study.

Relevance of the study

The results of this study have revealed that majority of the stunted children were classified as normal by BMI-for-age, indicating that their poor nutritional status was not picked up using a single metric of BMI-for-age. This finding assumes relevance in public health practice as it indicates that height-for-age is a vital metric for assessment of nutritional status of adolescents along with other metrics.

Authors Contribution

ARJ– Concepts, Design, Definition of intellectual content, Literature search, Data Interpretation, Manuscript preparation, Manuscript editing, Manuscript review, Guarantor.**BB**- Concepts, Design, Literature search, Data acquisition, Statistical analysis, Data Interpretation, Manuscript preparation, Manuscript editing, Manuscript review, Guarantor. **ST**-Concepts, Design, Definition of intellectual content, Statistical analysis, Data Interpretation, Manuscript editing, Manuscript review.

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Tables

TABLE 1 DISTRIBUTION OF HEIGHT-FOR-AGE AMONG THE STUDY SUBJECTS N=752

Category	Height for age z-scores	N (%)	Male 382 (50.8)	Female 370 (49.2)
Tall	> 2	05 (0.7)	02 (0.5)	03 (0.8)
Normal	-2 to +2	642 (85.4)	328 (85.9)	314 (84.9)
Stunted	< -2 to -3	93 (12.4)	48 (12.6)	45 (12.2)
Severely stunted	< -3	12 (1.6)	04 (1.0)	08 (2.1)

Numbers in parentheses are column percentages; Chi square= 1.744, P= 0.627

TABLE 2 COMPARISON OF STUNTING AND BMI-FOR-AGE AMONG THE STUDY SUBJECTS N=752

Category	Total N (%)	Normal/tall 647 (86%)	Stunting /severe stunting 105 (14%)	*P* value
Obese /Overweight	100 (13.3)	92 (92.0)	8 (8.0) †	**0.049***
Normal	552 (73.4)	475 (86.1)	77 (13.9)†	
Thinness / Severe thinness	100 (13.3)	80 (80.0)	20 (20.0)	

† adolescents who are stunted but whose poor nutritional status is not picked up by BMI-for-age. The numbers in parentheses are row percentages, except in the total column where they are column %

TABLE 3 PREVALENCE OF STUNTING ACROSS DIFFERENT ADOLESCENT AGES IN BOTH SEXES N=752

Age in completed years	Male (n=382)		Female (n=370)	
	Stunting %	**95% CI**	**Stunting %**	**95% CI**
10	6.9	5.1 – 8.7	0	-
11	10.8	8.6 – 13.0	20.7	17.1 - 22.9
12	9.1	7.0 – 11.2	11.1	9.9 – 13.3
13	10.7	8.5 - 12.9	6.8	5.0 - 8.6
14	18.8	16.0 – 21.6	7.5	5.6 - 9.4
15	9.3	7.2 – 11.4	17.8	15.1 – 20.5
16	8.8	6.8 – 10.8	23.6	20.6 -26.6
17	20.5	17.6 – 23.4	24.1	21.0 – 27.2
18	35.7	32.2 – 39.1	29.4	26.1- 32.7
19	27.3	24.1 – 30.5	33.3	29.9 – 36.7

CI: Confidence Interval; The numbers in parentheses are row percentages, except in the total column where they are column percentages

TABLE 4 ASSOCIATION BETWEEN STUNTING AND VARIOUS SOCIO-DEMOGRAPHIC FACTORS N=752

Variable	Category	Total N (%)	Normal/tall 647 (86%)	Stunting /severe stunting 105 (14%)	*P* value*
Age	Early adolescence	451 (60.0)	404 (89.6)	47 (10.4)	**<0.001†**
	Late adolescence	301 (40.0)	243 (80.7)	58 (19.3)	
Sex	Male	382 (50.8)	330 (86.4)	52 (13.6)	0.778
	Female	370 (49.2)	317 (85.7)	53 (14.3)	
Type of School	Government	371 (49.3)	299 (80.6)	72 (19.4)	**<0.001†**
	Private	381 (50.7)	358 (91.3)	33 (8.7)	
Socio-economic class	Upper/upper middle	166(22.1)	155 (93.4)	11 (6.6)	**0.002**
	Middle	238 (31.6)	207 (87.0)	31 (13.0)	
	Low/lower middle	348 (46.3)	285 (81.9)	63 (18.1)	
Type of Family	Nuclear	553 (73.5)	472 (85.4)	81 (14.6)	0.36
	Joint/Extended	199 (26.5)	175 (87.9)	24 (12.1)	
Caste	General	694 (92.3)	604 (87.0)	90 (13.0)	**0.038†**
	Backward	58 (7.7)	43 (74.1)	15 (25.9)	
Age at menarche‡	9-12 years	109 (42.4)	97 (89.0)	12 (11.0)	0.284
	13-16 years	148 (57.6)	123 (83.1)	25 (16.9)	

**Chi-square test; † statistically significant at p<0.05; n=257 girls who attained menarche. The numbers in parentheses are row percentages, except in the total column where they are column percentages*

TABLE 5 ASSOCIATION OF STUNTING WITH DIETARY PRACTICES N=752

Variable	Category	Total N (%)	Normal/tall 647 (86%)	Stunting /severe stunting 105 (14%)	*P* value*
Diet	Vegan or Vegetarian	70 (9.3)	65 (92.9)	05 (7.1)	0.084
	Non-Vegetarian	682 (90.7)	582 (82.3)	100 (14.7)	

Skips meals often	Yes	509 (67.7)	434 (85.3)	75 (14.7)	0.377
	No	243 (32.3)	213 (87.7)	30 (12.3)	
Weekly iron and folic acid supplementation	Yes	117 (15.6)	94 (80.3)	23 (19.7)	0.067
	No	635 (84.4)	553 (87.1)	82 (12.8)	
Daily intake of fruits and vegetables	Nil	21 (2.8)	17 (81.0)	4 (19.0)	0.757†
	1-3 cups	401 (53.3)	347 (86.5)	54 (13.5)	
	≥4 cups	330 (43.9)	283 (85.8)	47 (14.2)	
Sugary fizz drinks ‡	Yes	573 (76.2)	494 (86.2)	79 (13.8)	0.804
	No	179 (23.8)	153 (85.5)	26 (14.5)	
Packaged snacks ‡	Yes	608 (80.9)	526 (86.5)	82 (13.5)	0.439
	No	144 (19.1)	121 (84.0)	23 (16.0)	
Bakery items ‡	Yes	600 (79.8)	513 (85.5)	87 (14.5)	0.389
	No	152 (20.2)	134 (88.2)	18 (11.8)	
Fast foods like Pizza / burger ‡	Yes	402 (53.5)	352 (87.6)	50 (12.4)	0.196
	No	350 (46.5)	295 (84.3)	55 (15.7)	

**Chisquare test; †Fischers exact test; ‡consumed at least once a week. The numbers in parentheses are row percentages, except in the total column where they are column percentages*

TABLE 6 ASSOCIATION OF STUNTING WITH PHYSICAL ACTIVITY N=752

Physical Activity	Category	Total N (%)	Normal/tall 647 (86%)	Stunting /severe stunting 105 (14%)	*P* value*
Mode of transport to school	Walk / Cycle	454 (60.4)	397 (87.4)	57 (12.6)	0.169
	Vehicle	298 (39.6)	250 (83.9)	48 (16.1)	
Participation in school sports	Yes	307 (40.8)	275 (89.6)	32 (10.4)	**0.020†**
	No	445 (59.2)	372 (83.6)	73 (16.4)	
Adequate physical activity	Yes	635 (84.4)	554 (87.2)	81 (12.8)	**0.026†**
	No	117 (15.6)	93 (79.5)	24 (20.5)	
Adequate sleep	Yes	333 (44.3)	286 (85.9)	47 (14.1)	0.915
	No	419 (55.7)	361 (86.2)	58 (13.8)	

**Independent sample t-test; † statistically significant at p<0.05*

TABLE 7 MULTIPLE LOGISTIC REGRESSION OF FACTORS ASSOCIATED WITH STUNTING‡ N=752

Variable	Category	Adjusted OR	95 % CI	*P* value
Age group	Early adolescent	1	-	**0.003***
	Late adolescent	**1.90**	**1.24 – 2.90**	
Type of School	Government	6.69	0.92 – 22.75	0.102
	Private	1	-	
Socio-economic status	Upper/upper middle	1	-	
	Middle	1.92	0.93 – 3.96	0.080
	Low/lower middle	**2.75**	**1.39 – 5.41**	**0.003***
Caste	General	1	-	0.102
	Backward	2.02	0.88 – 4.77	
Diet	Vegan/Vegetarian	1	-	0.076
	Non-Vegetarian	2.35	0.91 – 6.06	
Weekly iron and folic acid supplementation	Yes	1	-	**0.001***
	No	**2.78**	**1.48 – 5.21**	
Fast foods like Pizza / burger †	No	1	-	0.099
	Yes	1.86	0.89 – 3.87	
Mode of transport to school	Walk / Cycle	1	-	0.518
	Vehicle	1.22	0.67 – 2.22	
Participation in school sports	Yes	1	-	0.370
	No	1.33	0.72 – 2.45	
Adequate physical activity	Yes	1	-	0.764
	No	1.09	0.62-1.91	

** statistically significant at p<0.05 like † consumed at least once a week ‡ Cox and Snell R2 = 0.031*