A high prevalence of NCD multimorbidity in South African Adolescents and Youth Living with HIV: Implications for Integrated Prevention

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Research

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Abstract

Background: Adolescents and youth living with HIV (AYLHIV) face an elevated NCD risk resulting from HIV, psychosocial challenges and the complications of antiretroviral therapy (ART).

Methods: We conducted a cross-sectional study in six primary care facilities to investigate the prevalence of common NCDs and risk factors among AYLHIV in Cape Town, South Africa between March 2019 and January 2020. We collected socio-demographic information, ascertained behaviours and knowledge and screened for pre-existent and previously unidentified NCDs and risk factors in adolescents and youth enrolled for primary HIV care. Characteristics between sexes and age groups were compared using parametric or non-parametric statistical tests.

Results: Three out of four participants were female, and the median age was 20.5 years (IQR 18.9- 22.9). More than a quarter were not in education, employment or training (NEET) and 44% were multidimensionally poor. Our results show an existent burden of hypertension (5%) and central obesity (37%) as well as high levels of depression (43%) and psychological distress symptoms (44%). AYLHIV further self-reported high levels of household food insecurity (70%), low fruit and vegetable consumption, high fast-food and sugar-sweetened beverage intake, low nutritional knowledge and insufficient physical activity. Beyond the NCD risk attributable to HIV and ART, these multiple risk factors further increase NCD risk.

Conclusions: Our findings highlight the importance of integrated prevention with NCD risk screening as part of HIV care for AYLHIV and the need for early intervention on social, environmental and economic determinants of NCDs targeting adolescents and youth.

Background

Globally, non-communicable diseases (NCDs) are the leading cause of disability and premature mortality accounting for 71% of deaths worldwide and 80.6% of years lived with disability (YLD) in 2016 [1,2]. NCDs are rising globally and affect low- and middle-income countries (LMICs) disproportionately, with more than three-quarters of NCD deaths occurring in LMICs [3]. Of note, unhealthy diets and physical inactivity which are significantly associated with obesity, diabetes, cardiovascular disease and cancers are rising globally, particularly in LMICs [2,4,5]. ()()()

In 2017, the burden of NCDs in sub-Saharan Africa (SSA) was higher than the global average, almost equivalent to the total burden associated with communicable, maternal, neonatal, and nutritional (CMNN) diseases [6], with rapid urbanization contributing to unhealthy diets and sedentary behaviour, especially amongst the poor residing in urban settings [7]. Epidemiological analyses from 1980–2014 show that age-standardized average body mass index (BMI) and diabetes prevalence have increased steadily across Africa, at least as steeply as the global average [8].

In South Africa, an upper-middle-income country, the prevalence of NCDs and NCD risk factors has increased over the last two decades. South Africa is said to be undergoing rapid epidemiological transition with a quadruple burden of disease [9]. To illustrate, the prevalence of overweight and obesity among adult South African women increased from 56% to 68% between 1998 and 2016 [10] and 51% of deaths were attributable to NCDs in 2016 [11]. One in three South African adults has hypertension, 16.2% smoke daily [12], 18.3% engage in heavy episodic drinking [13] and more than 30% of females and a quarter of males reported experiencing psychological distress [12].

Importantly, this rising NCD risk is also occurring in children and adolescents [14]. Adolescence is a critical period of both opportunity and risk accompanied by rapid physical and psychological development that sets the foundation for adult health [15,16]. Many NCD-related risk factors are initiated or reinforced during adolescence, which makes it a critical period for intervention to prevent future disease. Despite knowledge that many of these diseases and risk factors start in adolescence, there has been little focus on NCD prevention in this age group. South Africa has the highest prevalence of childhood and adolescent overweight and obesity in sub-Saharan Africa (19% of boys and 26% of girls under 20 years) rivalling that of many high-income countries [17]. Overweight and obesity rates have increased steadily especially amongst adolescents residing in urban settings [18] with over 40% of young people reporting insufficient levels of physical activity, and 30% spent more than three hours per day sedentary [14].

NCDs in LMICs are occurring in the context of persisting high infectious disease prevalence [19]. In South Africa, this is occurring alongside a persisting high burden of HIV/AIDS and tuberculosis [20]. South Africa has the largest HIV epidemic and antiretroviral treatment (ART) programme in the world, with 7.5 million people documented to be living with HIV in 2019 and 5.2 million on ART [21]. Of note, this includes adolescents and youth, with South Africa reporting the highest burden of adolescent HIV globally [22]. Of the 1.6 million adolescents reported to be living with HIV worldwide in 2018, 19% are South African [22].

HIV and ART are associated with several NCDs. Evidence on increased prevalence of NCD comorbidities has been documented in adults living with HIV (PLHIV) [23], with an excess burden of NCD risk factors in PLHIV compared to the general population [24]: 49% are insufficiently physically active [25], 40–70% are current smokers [26,27] and 37-66% are current drinkers [28,29]. In South Africa, almost half of adult patients attending HIV clinics in Cape Town engaged in hazardous alcohol use, and 15% had problematic drug use [30].

Adolescents and Youth living with HIV (AYLHIV) face elevated health risks [31,32] with similar comorbidity patterns to adults identified in paediatric and adolescent cohorts worldwide as a consequence of HIV and long term ART but not necessarily in the context of rapid epidemiological transition Of note, given that AYLHIV routinely access care, and are potentially additionally vulnerable to NCDs, there is an opportunity for early intervention to identify risk factors and prevent other comorbidities. Where these services have been integrated with HIV care among adolescents and youth, such services have largely focused on reproductive health [33,34] with little to no focus on NCDs.

A previous study explored this missed opportunity in Cape Town reviewing clinical folders of AYLHIV to identify the extent to which NCD risk factor screening is routinely implemented. This study demonstrated that despite evidence of existing NCD comorbidity and risk factors in AYLHIV, there was limited integration of NCD screening and health promotion in adolescent and youth HIV healthcare services [35]. This raises questions about the true prevalence of NCD multimorbidity in this population group needed to inform service delivery.

Of note, while previous studies of AYLHIV in SSA have described risks associated with sexual behaviour [36,37] tobacco and substance use [38,39], there is overall data paucity on the breadth of NCDs and associated risk factors in this population group in SSA. With the first cohorts of AYLHIV now entering adulthood and the move towards more comprehensive health services aimed at improving the quality of life of PLHIV, questions remain on the prevalence of NCD comorbidity and NCD risk factors in AYLHIV and the best way to ensure holistic adolescent health and well-being.

We thus aimed to assess the prevalence of the most commonly occurring NCDs and risk factors that could benefit from early intervention, with a focus on cardiometabolic, respiratory and mental health conditions and risk factors in AYLHIV accessing primary health care in urban Cape Town.

Methods

Study Setting and Population

We conducted a cross-sectional study of AYLHIV aged 15 - 24 years attending primary care health facilities in Cape Town. Cape Town is the second biggest metropolitan city in South Africa with an estimated population of 4.2 million people [40]. In 2016, adolescents and youth aged 15 - 24 years comprised 16.3% of the population in the Western Cape province, within which Cape Town is located [10]. NCDs and HIV are ranked amongst the top causes of premature deaths in the City of Cape Town [41], with the top five causes of death in 2016 ranked as diabetes mellitus, HIV, ischaemic heart diseases, cerebrovascular diseases and TB [42].

The City of Cape Town delivers primary health care through four legislated substructures: Khayelitsha / Eastern, Mitchells Plain / Klipfontein, Western / Southern and Northern / Tygerberg [41]. Recruitment and data collection took place at six public sector HIV clinics, with 1 - 3 clinics selected within each of the four sub-structures (**Figure 1**). These facilities serve patients living in peri-urban, high-density, low-income townships, collectively known as the Cape Flats

Study Design and Sampling

The sample size was determined using prevalence estimates for obesity (for which data are readily available) from the South African National Health and Nutrition Examination Survey 2012 for the 15 - 24 years age group [12]. The confidence level was set at 95%, with a 5% degree of precision, and an obesity prevalence of 5.6%, yielding a minimum required sample size of 86, adjusted for a 5% non-response rate.

Prior to data collection, we conducted stakeholder engagement, liaising with facility managers and youth healthcare providers to optimise recruitment strategies for each clinic. We previously described the method used to estimate the number of AYLHIV accessing care at each facility [35]. Details of the study were shared at each AYLHIV clinic and a convenience sampling approach was used. Participant recruitment commenced in March 2019 after ethical clearance was obtained from the University of Cape Town Faculty of Health Sciences Human Research Ethics Committee (HREC ref no: 520/2017) and approval from Provincial and Local Government Departments of Health. Parents or legal guardians gave permission for their children to participate in the study, and participants provided informed assent (or consent if 18 years or older). Recruitment and study procedures were then conducted after gaining written informed consent and assent at six facilities until January 2020 (**Figure 1**). Participants received reimbursement for transport costs.

Figure 1: Participant Recruitment and enrolment at respective facilities

Study Procedures

Socio-demographic characteristics

Adolescence: can be categorized into three primary developmental stages; early adolescence (10 - 14 years), middle adolescence (15 - 17 years), and late adolescence / young adulthood (18 - 24 years) [43]. For the purposes of this study, we categorized participants into four age groups in line with these stages, further sub-dividing the oldest age group as follows: 15 - 17, 18 - 19, 20 - 21 and 22 - 24 years.

Deprivation: Questions on socioeconomic status were derived from the 2011 South African Census [44] and deprivation assessed using the Youth Multidimensional Poverty Index (YMPI) comprising eleven weighted indicators in five dimensions: educational attainment, general health and functioning, living environment, household assets and employment [45]. An individual was defined as being multidimensionally poor – MPI poor– if they were deprived in a third or more of the weighted indicators, with a composite score ≥ 33.3% [45].

Food insecurity: was measured using the Household Food Insecurity Access Scale (HFIAS) score [46]. Participants were categorized as living in food secure, mildly–, moderately–, or severely food insecure households according to the HFIAS protocol [47].

Behaviour and Knowledge

Physical activity: was assessed using the International Physical Activity Questionnaire (IPAQ) [48], validated in youth and adults in South Africa [49]. We used the Ainsworth et al. scoring algorithms to derive an average metabolic equivalent of task (MET) intensity level score for each type of physical activity: vigorous, moderate, walking and cycling [50]. Physical activity levels were further categorized according to the IPAQ scoring protocol into low, moderate and high [51]. Insufficient physical activity was defined as a score below 600 MET minutes/week [52]. The presence or absence of sedentary behaviour

was dichotomized as spending three or more hours per day watching television, playing computer games, talking with friends or other sitting activities [53].

Dietary intake: was assessed using a 23-item food frequency questionnaire (FFQ) adapted from the Health Behaviour in School-aged Children Survey [54] validated for use in adolescents [55]. We estimated the proportion who ate fresh fruits and vegetables daily (once or more than once a day in the previous week) and frequently (on four or more days in the previous week) and the proportion of respondents who reported daily consumption of sugar-sweetened beverages (SSB), deep-fried foods, fast foods, salty snacks, and processed meats. Skipping breakfast was defined as eating breakfast on 0 - 2 days/week; semi-skipping, 3 - 4 days/week and not skipping, 5 - 7 days/week.

Nutritional knowledge: was assessed using a revised General Nutrition Knowledge Questionnaire (GNKQ-R), validated for use in young people [56]. A nutritional knowledge score was generated by totalling correct answers in four nutrition domains. The maximum possible score was 88; 18 for questions on "dietary recommendations", 36 for questions on food groups, 13 for "healthy food choices" and 21 for "associations between diet and disease". No norms exist to determine an adequate nutrition knowledge score [57]. Hence we computed the average nutrition knowledge score and compared the mean scores for each of the nutrition domains by gender and age groups comparable to a previous study of South African adults [58]. The percentage of respondents who answered the questions correctly in each domain was calculated.

Comorbidities

Respiratory disease: was defined as self-reported pre-existing diagnosis of asthma, tuberculosis, bronchitis, or other lung disease. Experiencing any of the following symptoms in the preceding three months was characterized as presence of respiratory symptoms: prolonged cough with sputum for more than two weeks, chest tightness, shortness of breath, difficulty breathing; or having an abnormal peak flow reading (using a hand-held peak flow meter in accordance with standard guidelines [59]).

Diabetes: was defined either as i) a pre-existing self-reported diagnosis; ii) a random blood glucose reading of > 7 mmol/l (using a point-of-care (POC) glucometer with reactive test-strips (Glucocheck Evolve ® Homemed Pty) and having a family history of diabetes; or iii) a random blood glucose reading of > 7 mmol/l and experiencing diabetes-related symptoms over the past three months: frequent urination, increased thirst, unexplained weight loss of more than 1.5 kg in the last month, unexplained fatigue, blurry vision.

Blood pressure: Sitting blood pressure (BP) was measured using a Rossmax automatic blood pressure monitor (Rossmax (Shanghai) Incorporation Ltd) using the South African hypertension practice guidelines [60].

Depression and psychological distress: were defined using symptom screening questions from the 10-item Centre for Epidemiological Studies Short Depression Scale (CESD-10) [61,62] and the Kessler

Psychological Distress Scale (K10) [63]. Both tools have been validated in South African PLHIV [64,65] and in adolescents and young adults [66]. Depression was defined as a binary indicator using a cut-off score of 10 or more on the CESD-10 scale [61] and the likelihood of psychological distress was categorized according to the K10 score: K10 < 20: mentally well; K10 20 – 24: likely to have mild psychological distress; K10 25 – 29: likely to have moderate psychological distress; K10 30 – 50: likely to have severe psychological distress [67].

Overweight and obesity: Height, weight and waist circumference (WC) were measured according to the WHO STEPS Protocol [68]. The abdominal obesity cut-off point for a high WC was ≥ 102 cm in males and ≥ 88 cm in females and a waist-hip ratio (WHR) > 0.85 for females and > 0.90 for males [68]. Waist-to-hip ratio was calculated by dividing the WC by the hip circumference in centimeters rounded to two decimal places. A threshold value of 0.5 for the waist-to-height ratio (WHtR) was used as a measure of central obesity, calculated by dividing the WC by the height in cm [69].

Statistical Analysis

Graphical data exploration and Shapiro-Wilk's tests were used to test for normality of variables. All data were analysed and stratified by sex and age. Demographic and socioeconomic variables were described using summary statistics (frequencies, percentages, median and interquartile range (IQR)). Characteristics between sexes and age groups were compared using Pearson's $\chi 2$ and Fisher's exact tests for categorical measures. The Wilcoxon-Mann-Whitney test was used to compare medians between groups and the Kruskal-Wallis test was used for comparing continuous measures in more than two groups. All tests of significance were two-tailed and performed at the 5% significance level. Data analysis was conducted using Stata version 14.0 (*StataCorp, College Station, Texas, USA*).

Results

Socio-demographic baseline characteristics

A total of 176 adolescents and youth were recruited and invited to participate, of which 92 were successfully interviewed. The majority (76%) were female and the median age was 20.5 years (IQR 18.9–22.9)(See Table 1). The majority lived with a biological parent or a relative. More than a quarter of female respondents reported ever being pregnant. Overall, 44% of participants can be considered multi-dimensionally poor as they were deprived in a third or more of the five dimensions of MPI indicators (Table 1). More than half were living-environment deprived with over a third living in informal housing, 28% living in households that do not use electricity, gas or solar power for heating and 17% living in households without piped water available on site. Almost a quarter of respondents were deprived in educational attainment and 39% were economically deprived: 27% were neither in education, employment or training (NEET) , while 15% were living in households with no employed adults of working age and 3% were deprived in both economic indicators**.** The majority of participants were living in food insecure households with 38% considered as severely food insecure: either having to cut back on meal size, number of meals or going a whole day and night without eating in the last month.

Behaviour and Knowledge

Physical activity

Overall, a third of respondents had insufficient levels of weekly physical activity, 41% had moderate levels and 27% had high levels of physical activity. A greater proportion of males had high levels of physical activity compared to females (44% vs 22% respectively). The total median MET-minutes of physical activity a week including active transport) was higher for males compared to females, but this was not statistically significant (Table 2). The youngest age group reported the highest rates of vigorous-intensity physical activity (Table 3). Over two-thirds of all participants (84% males; 67% females) reported using active transport in the preceding week (mostly walking to school/work for at least ten minutes continuously). Almost half of respondents spent more than three hours sedentary during a typical day, with no difference in sedentary behaviour by gender.

Dietary intake

Overall, less than a third of respondents ate fruits and wholegrains daily (Table 2) with significantly more males reporting eating fruit frequently compared to females. More than half ate vegetables daily (either dark green, orange or other vegetables) and younger adolescents had the lowest daily consumption of fruits, vegetables and wholegrains compared to older age groups. A third of respondents had a high dietary intake of sugar; either reporting drinking SSB daily or eating sweets and cakes daily. SSB consumption was similar across gender and age groups. Older adolescents aged 18–19 years had the highest daily consumption of deep-fried and fast foods compared to other age groups (Table 3).

Meals eaten outside the home

Two-thirds of respondents ate at least one meal that was prepared outside the home in the previous week. Those who ate food prepared outside the home, ate a median of two take-away or sit-down meals in the past week (IQR 2–4 meals). Males had a larger variability in meals consumed that were prepared outside the home compared to females.

Breakfast

Over half of participants reported eating breakfast on at least five days in the previous week, one in five participants ate breakfast on 3–4 days in the week and one in five reported skipping breakfast or eating breakfast on less than two days in the previous week. Skipping breakfast did not differ significantly by gender or age.

Nutrition Knowledge

Overall, the mean GNKQ-R score achieved by adolescents was 33 out of a total of 88 points (37.5%). Knowledge of dietary recommendations was the highest-scoring domain with an average of 44% while

knowledge of healthy food choices was the lowest-scoring domain at 32% average score.There were no significant differences in nutrition knowledge amongst adolescents by sex and age group (Figure 2).

Comorbidities and symptom screening

Respiratory diseases and symptoms

TB was the most common pre-existing comorbidity reported by 23% of participants. Less than 5% had a previous diagnosis of asthma (Table 4). Eleven participants (12%; 95% CI: 6.3–21%) reported experiencing one or more respiratory symptoms over the past three months. Peak flow measurement was performed for five participants who reported respiratory symptoms but had no known asthma diagnosis. All the measurements were within the normal –green– peak flow zone.

Diabetes

Only one participant (who also reported diabetes symptoms) reported a previous diabetes diagnosis. A quarter of participants (95% CI: 16–35%) reported experiencing one or more diabetes-related symptoms over the past three months (Table 4). Younger age groups (15–17 years and 18–19 years) reported more diabetes-related symptoms compared to older age groups (Table 5). Overall, 27% reported a family history of diabetes (95% CI: 18–37%). Of those with reported symptoms or a reported family history of diabetes who had their blood glucose measured (n = 31), none had a measured random blood glucose of more than 7 mmol/L.

Blood Pressure

Overall, 20% had an elevated blood pressure and 5% had hypertension. Figure 4 shows that the prevalence of elevated blood pressure and hypertension was higher in males compared to females (*p= 0.0367*). Systolic and diastolic blood pressure showed an increasing trend with age (Table 7). The median age of those with elevated blood pressure or hypertension was 21.2 (IQR 18.8 – 22.7) years, similar to those with normal blood pressure (median 20.2, IQR: 19.0 – 22.8 years). Of those with elevated blood pressure or hypertension,11 (35%) were overweight or had obesity and 2 (6%) reported a previous diagnosis of hypertension (data not shown in tables).

Depression and psychological distress

More than two-fifths of participants reported experiencing significant depression in the past week (95% CI: 32–54%). Female participants were significantly more likely to report depressive symptoms compared to males (Table 4 and Figure 3). Of those with significant depression, 6/35 (17%) reported a previous diagnosis of depression or anxiety. There were no significant differences in depression scores by age. Almost half the participants reported some level of psychological distress over the past month. Only 11% of those with mild to severe psychological distress reported previously being diagnosed with depression or anxiety. The prevalence of psychological distress symptoms was comparable across age groups (Table 5).

Overweight and obesity

A quarter of participants were overweight and 11% had obesity, with significant differences by gender (Figure 5). The median BMI for males was significantly lower than for females. A greater proportion of participants aged 18–19 years were overweight or obese compared to the other age groups (Table 5).

Abdominal obesity

There was a markedly significant difference in the waist-hip ratio (WHR) of males and females, with more than a quarter of females and no males with central obesity (Table 4). Using the WHtR, 44% of females had central obesity compared to 14% of males. WC increased with age, with those aged 22–24 years having the highest WC, but WHR did not differ by age. It is important to note that a quarter of participants with normal BMI had abnormal WHR and/or WHtR and could be classified as having central obesity.

Discussion

This study describes the prevalence of NCDs and NCD risk factors among South African AYLHIV in an urban setting. Previous studies in SSA have described NCD comorbidities in adults living with HIV [23]. Few studies have assessed the prevalence of NCDs and particularly NCD risk factors in AYLHIV in SSA. Risk behaviour research on AYLHIV in SSA has predominantly focused on sexual risk behaviour [70]. We therefore set out to investigate NCD multimorbidity and risk factors in this population group given the emerging NCD epidemic in SSA occurring against a background of a high HIV burden and increased comorbidity risk in PLHIV.

We highlight several key findings. Almost half of our participants experienced significant symptoms of depression and psychological distress. More than a third were overweight or obese, a third had insufficient levels of weekly physical activity and the majority did not meet dietary guidelines for fruit and vegetable intake. There was low nutritional knowledge, particularly on healthy food choices and diet-disease relationships. A detailed interpretation of these findings, comparisons to the general population and previous findings in PLHIV as well as implications for integrated prevention are discussed below.

More than two-thirds of our respondents were female which reflects the gendered nature of the HIV epidemic in South Africa [71], and much higher rates of health care-seeking among young women compared to young men [72]. A greater proportion of AYLHIV in this study were multidimensionally poor compared to national estimates which indicate that 33.4% of young people aged 15 - 24 years are MPI poor [73]. Although the proportion of NEETs in this study was lower than the national average of 34% [74], they experienced other dimensions of deprivation which may interact to exacerbate vulnerability to NCDs.

Previous studies in South Africa corroborate the findings that HIV/AIDS-affected and infected youth face multiple deprivations of poverty [75,76], and food insecurity [77], which are commonly cited challenges for adolescents receiving HIV treatment and care in SSA. This is concerning because socioeconomic

factors impact adherence to ART and retention in HIV care, which has implications for viral suppression and chronic disease pathways [78,79]. Addressing this challenge requires a multi-sectoral approach for NCD prevention with appropriate social protection systems to meet the needs of AYLHIV.

With respect to NCD risk factors associated with behaviour and knowledge, we found that almost three-quarters of AYLHIV did not meet recommended dietary guidelines of eating at least five portions of fruit and vegetables daily necessary to reduce the risk of NCDs [80]. Compared to provincial estimates for youth in the Western Cape, more respondents, particularly females, consumed deep-fried foods and fast-foods daily, while the proportion who consumed SSB daily was lower than the provincial average (42%) [10] and estimates from 44 other LMICs (44%) [81]. A meta-analysis on SSB intake found that individuals who consumed 1–2 servings per day had a 26% greater risk of developing type 2 diabetes mellitus (T2DM), and a 20% greater risk of metabolic syndrome compared to those who did not consume SSB or had less than one serving/month [82]. Although the South African government has made strides in promoting healthier food environments by implementing mandatory legislation for salt reduction in processed foods [83] and a tax on SSB [84], our findings suggest that greater efforts are needed to translate these measures into action at a community and household level, especially amongst young girls who have higher prevalence of obesity which is likely to persist until adulthood without intervention.

Our results support findings of gender differences in physical activity levels among South African adolescents similar to global reports [85,86]. More than two-thirds of our respondents used active transport; either walking to and from school or work. This is notable and important that future interventions to increase physical activity consider strategies to retain this healthy behaviour. However, fewer than one-third had sufficient levels of physical activity necessary to promote health and prevent chronic diseases. This is similar to physical inactivity levels reported in urban-based South African students [85]. The proportion who spent more than three hours per day sedentary was higher than general population estimates of 30% [14] and higher than estimates from other LMICs of 27% [81].

Our results are consistent with those from a study conducted in Botswana which found that youth living with HIV had significantly lower levels of daily physical activity compared to HIV negative controls [87]. Similarly, a study in Brazil in 10–15-year-old perinatally-infected adolescents found that participants living with HIV had lower physical activity scores compared to healthy peers [88]. Additional research is needed in this setting to explore the relationship between physical activity and HIV in adolescents. A study with an age-and sex-matched HIV-negative control group from the same community would help to elucidate whether this relationship exists in South Africa.

Participants scored low on general nutrition knowledge questions and particularly had poor knowledge of healthy food choices and associations between diet and diseases. To our knowledge, this is the first study to assess nutrition knowledge in AYLHIV in Africa. A South African study in school-going adolescents aged 15–18 years found that 77.5% scored below average on diet and nutrition knowledge questions [89]. The poor knowledge on nutrition-related NCDs amongst AYLHIV in our study is concerning in a country undergoing nutritional transition [90]. Nutrition knowledge is strongly correlated with dietary

intake and is needed for better dietary habits [57]. Although adolescents may lack autonomy in navigating their food environment, this life stage is characterised by increasing independence highlighting the importance of good dietary knowledge including how diet affects their current and future health [89] to support making healthier food choices.

Our blood pressure findings are consistent with findings from studies in adolescents in the general population of urban South Africa which have reported hypertension prevalence rates ranging from 8–16% [91] and elevated BP prevalence of 35% [92]. A study in the United States reported a significantly higher prevalence of elevated blood pressure in a cohort of HIV-infected, predominantly African-American adolescents and young adults compared to healthy children [93]. Globally, studies involving HIV-infected adults have demonstrated higher hypertension prevalence than the general population [94] and hypertension has been found to be associated with ART [95,96]. One in five young adults (18–35 years) attending an HIV clinic in the same setting in Khayelitsha were found to have comorbid hypertension [97]. There are conflicting data on the link between HIV infection and elevated BP in paediatric populations. Nevertheless, our findings support the need for routine monitoring of BP in HIV care, even in younger populations, in settings like South African with a high background prevalence of hypertension, in order to avert future disease.

None of those with self-reported diabetes symptoms had an abnormal random blood glucose. In a cohort study of South African youth living with perinatally-acquired HIV, the authors found a high prevalence of insulin resistance but this did not differ from that in HIV-negative age-matched adolescents [98]. A systematic review and meta-analysis of African studies recently reported that there was no statistically significant association between HIV infection or ART exposure and T2DM in adults [99]. This is in contrast to findings from European and North American studies that have shown a higher prevalence of T2DM in HIV-positive adults particularly those on ART [100-102]. The International Diabetes Federation (IDF) estimates that 60% of people with diabetes in Africa are undiagnosed [103] suggesting that T2DM might be a major, underdiagnosed public health problem in African populations in general, warranting further attention.

We found high levels of depression and psychological distress in our study compared to less than a quarter of young people nationally [12]. Concerningly, only 11% of those with mild to severe psychological distress reported previously being diagnosed with a mental health condition highlighting a significant gap in care. Mental health conditions are prevalent in AYLHIV in both high-income and resource-limited settings [104]. Our results are generally consistent with prevalence rates of depression among children and adolescents living with HIV from other African countries ranging from 18.9% in Malawi [105] to 51.2% prevalence of psychological distress in Uganda [106].

Notably, significantly more female participants reported depressive symptoms compared to males which is in line with global statistics on depression [107]. Our findings show that only 17% of those identified as having significant depression reported being previously diagnosed with anxiety or depression. In a previous retrospective review in the same population, mental health conditions were documented in less

than 5% of clinic records reviewed [35]. In a recent study conducted in South Africa, the authors found similar rates of mental illness in perinatally-infected and uninfected adolescents, suggesting that other prevalent social factors in the community may override the effect of HIV, especially in the ART era [108]. Nevertheless, these findings highlight that there is a significant missed opportunity for identifying youth with mental health problems in our setting.

More than a third of our respondents were overweight or had obesity, with significantly more overweight and centrally obese females compared to males. Although our rates of overweight and obesity are slightly lower than prevalence rates for youth in the Western Cape (31.5% overweight and 11.3% obese) [14], our rates appear similar to obesity trends in the general population. A previous study in adult patients attending primary health care HIV-clinics in South Africa found that more than half of female patients were overweight or had obesity compared to 16% of male patients [109]. Obesity in PLHIV is well documented in high-income countries and is emerging as a major challenge in Africa [24] with several studies showing increased rates of obesity in PLHIV [109,110]. But few studies in Africa have reported on overweight and obesity levels in AYLHIV other than in the context of ART-associated dyslipidaemia [87,111,112]. One study conducted among South African university students living with HIV (the majority aged 20–25 years) found that 21% were overweight and 30% had obesity [113]. Our results are consistent with these findings and confirm results from a folder review conducted in this same population that reported similar levels of overweight and obesity [35].

In addition to BMI, we assessed central obesity using waist and hip circumference indicators and found that 26% of our respondents with normal BMI had high WHR or WHtR, meeting criteria for central obesity. Another South African study in adults attending three HIV-clinics reported a high prevalence of central obesity, primarily in women – 45% (4% in men) [113].

Implications for integrated care

Our findings underscore the importance of anthropometry beyond BMI, especially in females. In a comparison of anthropometric measures in HIV patients in Cameroon, Dimala et al found that markers of adiposity like WC, WHR and WHtR are better than BMI at identifying HIV/AIDS patients with increased cardiometabolic risk [114]. In our study, obesity co-occurred with hypertension – 35% of those with elevated BP or hypertension were also overweight or obese (data not shown). By screening for obesity, other related conditions which tend to cluster with obesity can also be detected. Given that anthropometric measurements and calculations are non-invasive, low-cost and easy-to-use interventions, our findings support the need to integrate this screening into routine care to identify AYLHIV who are at increased cardiometabolic risk and intervene early as they transition into adulthood, especially with prolonged exposure to ART regimens which are linked to obesity, altered glucose metabolism and dyslipidaemia [115]. This is supported by the WHO and the IDF who recommend monitoring changes in WC in addition to measuring BMI, particularly in HIV-positive populations on ART and in female patients who have a higher prevalence of obesity [68,116].

Recommendations calling for integration of mental health services into HIV care have been made for adults [117] given the multiple psychological vulnerabilities associated with living with HIV and high rates of suicide in PLHIV [118,119]. Our findings further support the need for integration of mental health screening in HIV care for AYLHIV. A study conducted in Johannesburg found that a simple way of identifying youth struggling with mental health problems at primary care level is by asking them about their future aspirations. Those who do not feel like they have control of their future or do not have a dream for the future were found to be more likely to have symptoms of depression, anxiety or PTSD requiring further support [120].

The recently introduced integrated chronic disease management (ICDM) model in South Africa recognises the importance of monitoring both chronic communicable and NCDs in order to achieve optimal clinical outcomes [121]. Our findings underscore the importance of applying an evidence-based integrated approach to the healthcare services for AYLHIV. In the context of resource limitations, further research exploring the multilevel determinants of these NCDs and their risk factors would be useful to inform tailored strategies to identify those at highest risk.

Strengths and Limitations

Our study adds to the limited evidence base on NCD prevalence and risk factors in AYLHIV in SSA. To our knowledge, only four other studies in SSA have investigated modifiable NCD risk factors besides alcohol and substance use in AYLHIV [87,113,122,123]. While our study provides novel findings for the sub-Saharan African context, we note some limitations.

The low response rate and lack of random sampling may limit the generalizability of our findings, however sampling from six different facilities across all substructures in the City of Cape Town mitigated unmeasured facility-specific effects. Although we recruited younger adolescents, requiring parental consent may have led to participant bias as the majority enrolled were older adolescents and young adults who could provide independent consent to participate.

We utilised subjective recall methods to asses physical activity which may be prone to over-reporting, recall bias and cultural misinterpretation. However, self-report methods like the IPAQ have acceptable validity and have been widely used to measure physical activity in PLHIV in similar contexts allowing for some comparability [25]. The use of POC random blood glucose testing may have underestimated diabetes risk, however, POC methods are better suited for community screening of diabetes, have high specificity and provide reliable and immediate results [124]. Similarly, the mental health tools used are screening and not diagnostic tools. But they are appropriate for case-finding in primary care and have been validated in HIV-positive populations in South Africa [64,65]. Despite these limitations, this study represents an important contribution to the limited literature on HIV / NCD multimorbidity in adolescents and youth in SSA.

Conclusions

This paper contributes to a key gap in the literature on NCD risk in AYLHIV in SSA. The findings highlight the existence of cardiometabolic risk factors (obesity, abdominal obesity, hypertension, physical inactivity, unhealthy diet) and mental ill-health in this vulnerable population, highlighting the need for integrated comprehensive care for AYLHIV with NCD screening and integrated primary and secondary prevention.

NCDs and their ensuing burden of disability and premature mortality are costly to health systems and to wider societal development. Beyond primary care, the complex and interlinked social, economic and environmental factors that influence these behaviours highlight the importance of intersectoral action for disease prevention. Addressing these root causes will therefore necessitate intervention beyond the healthcare sector to address the social, economic and environmental exposures that increase the risk of NCDs and ill-health, and to support equitable access to the necessary physical and social infrastructure required to make the healthy choice the easy choice. More studies are needed to assess risk factors at a broader socio-ecological level and explore inter-relationships between HIV / NCD comorbidity and the multilevel determinants of multimorbidity.

List Of Abbreviations

AYLHIV: Adolescents and youth living with HIV;

BMI: Body mass index;

BP: Blood pressure;

CESD-10: Centre for Epidemiological Studies Short Depression Scale;

CMNN: Communicable, Maternal, Neonatal, and Nutritional;

FFQ: Food frequency questionnaire;

GNKQ: General Nutrition Knowledge Questionnaire;

HFIAS: Household Food Insecurity Access Scale;

IDF: International Diabetes Federation;

IPAQ: International Physical Activity Questionnaire;

K10: Kessler Psychological Distress Scale;

LMIC: Low- and middle-income countries;

MET: Metabolic equivalent of task;

NCD: Non-communicable disease;

NEET: Neither in education, employment or training;

PA: Physical activity;

PLHIV: People living with HIV;

PTSD: Post-traumatic stress disorder

SSA: Sub-Saharan Africa;

SSB: Sugar-sweetened beverages;

T2DM: Type 2 diabetes mellitus

WHO: World Health Organization;

WC: Waist circumference;

WHR: Waist-hip ratio;

WHtR: Waist-to-height ratio;

YMPI: Youth Multidimensional Poverty Index.

Declarations

Ethics approval and consent to participate: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Human Research Ethics Committee in the Faculty of Health Sciences at the University of Cape Town (HREC ref.no 520/2017), and the Health Research Ethics Committees of the City of Cape Town and the Western Cape provincial government. Written informed consent was obtained from all individual participants included in the study. Parental or caregiver written consent and participant assent were obtained for participants younger than 18 years old.

Consent for publication: Not applicable.

Availability of data and materials: The data that support the findings of this study are not publicly available due to the sensitive nature of information that could compromise minor research participants' privacy/consent but are available from the corresponding author MK on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: MK and TO conceptualized the study. MK and BG conducted data collection. MK conducted data analysis and interpretation and wrote the first draft of the manuscript. TO contributed to data interpretation and manuscript preparation. All authors read and approved the final manuscript.

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Tables

TABLE 1: Participant Socio-demographic, baseline characteristics by Gender

Variable	Description Median (IQR) or n (%) ($p < 0.05$)[1]	Male: n= 22 (24%)	Female: n=70 (76%)	Total n= 92
Age (years)		20.7 (18.9 - 21.6)	20.4 (19.0 - 23.0)	20.5 (18.9- 22.9)
Adolescent stage by age group	middle adolescence: 15–17 years	3 (14%)	10 (15%)	13 (14%)
	late adolescence: 18–19 years	5 (23%)	18 (26%)	23 (26%)
	young adulthood: 20–21 years	9 (41%)	16 (24%)	25 (28%)
	young adulthood: 22–24 years	5 (23%)	24 (35%)	29 (32%)
Family structure- whom they live with	Biological parents	10 (45%)	35 (50%)	45 (49%)
	Grandparents	4 (18%)	8 (11%)	12 (13%)
	Relative (aunt or uncle)	6 (27%)	23 (33%)	29 (32%)
	Siblings	15 (68%)	33 (47%)	48 (52%)
	Non-family (foster care/ children's home)	0	2 (3%)	2 (2%)
Ever pregnant/ impregnated someone (*p= 0.023)*		1 (5%)	19 (28%)	20 (22%)
Parity (n= 20)	0 children	0	5 (26%)	5 (25%)
	1 child	1 (100%)	13 (68%)	14 (70%)
	2 children	0	1 (5%)	1 (5%)
Current occupation/ employment status	In school/college/university/ other tertiary education	7 (32%)	37 (54%)	44 (48%)
	In training	3 (14%)	6 (9%)	9 (10%)
	Employed	5 (23%)	8 (11%)	13 (14%)
	Not in education, employment or training (NEET)	7 (32%)	18 (26%)	25 (27%)
Ever repeated a grade at school		14 (64%)	33 (47%)	47 (52%)
Days absent from school or work in past month	0 days	13 (59%)	34 (49%)	47 (52%)
	1 – 2 days	7 (32%)	26 (38%)	33 (36%)
	3 or more days	2 (9%)	9 (13%)	11 (12%)
Youth multidimensionally poor[2] **(n= 88)**		9 (41%)	30 (45%)	**39 (44%)**
Educational attainment		4 (18%)	16 (24%)	20 (22%)
	Aged 17 – 20 & completed less than nine years of schooling	1 (5%)	2 (3%)	3 (3%)
	Aged 21 – 24 & completed less than matric or equivalent	3 (14%)	14 (21%)	17 (19%)
General health and functioning		16 (73%)	46 (67%)	62 (68%)
	Difficulty hearing	3 (14%)	13 (19%)	16 (18%)
	Difficulty seeing	7 (33%)	26 (39%)	33 (38%)

	Difficulty moving around	2 (10%)	15 (22%)	17 (20%)
	Difficulty concentrating	12 (57%)	32 (48%)	44 (50%)
	Difficulty with self-care	0	14 (21%)	14 (16%)
Living environment		0 (0 - 0.036)	0.036 (0 - 0.071)	0.036 (0 - 0.071)
	Fuel for lighting other than electricity, gas/ solar power	0	1 (1%)	1 (1%)
	Fuel for heating other than electricity, gas/ solar power	5 (23%)	21 (30%)	26 (28%)
	Fuel for cooking other than electricity or gas	0	1 (1%)	1 (1%)
	Sanitation: Household without a flush toilet	3 (14%)	5 (7%)	8 (9%)
	Water: Household without piped water on site	1 (5%)	15 (21%)	16 (17%)
	Dwelling that is an informal shack /caravan/ tent/ other	4 (18%)	28 (41%)	32 (35%)
Household assets[3]: Household with ≤ two assets below & no motor vehicle		3 (14%)	20 (29%)	23 (25%)
	no radio	9 (41%)	32 (46%)	41 (45%)
	no television	2 (9%)	6 (9%)	8 (9%)
	no landline	22 (100%)	67 (96%)	89 (97%)
	no cell phone	1 (5%)	14 (20%)	15 (16%)
	no refrigerator	6 (27%)	24 (34%)	30 (33%)
	no motor vehicle (*p= 0.003)*	10 (45%)	55 (79%)	65 (71%)
Household adult unemployment: no employed adults (18 – 64 years)		1 (5%)	13 (19%)	14 (15%)
Household Food Insecurity Access Score		2.5 (1 – 5)	3 (0 – 7)	3 (0 – 7)
	food secure	4 (19%)	24 (34%)	28 (30%)
	mildly food insecure	7 (32%)	11 (16%)	18 (20%)
	moderately food insecure	4 (19%)	7 (10%)	11 (12%)
	severely food insecure	7 (32%)	28 (40%)	35 (38%)

[1] P-value shown if significant at 5% level: $p < 0.05$;

[2] Youth MPI poor: those with composite score > 33.3%;

[3] Individual living in a household that does not own more than two of: radio, TV, landline, mobile phone, bike, motorbike or refrigerator AND does not own a motor car or truck

TABLE 2: Physical Activity, Sedentary and Dietary Behaviour and Nutritional Knowledge of AYLHIV by Gender

Variable: Median (IQR) or n (%)	Description	Male: n= 19 (22%)	Female: n= 67 (78%)	Total: n =86
Vigorous-intensity Physical activity	Any vigorous-intensity PA for ≥10 minutes	11 (58%)	26 (39%)	37 (43%)
	Time spent doing vigorous-intensity PA per day in minutes	75 (30 – 240)	60 (30 – 120)	60 (30 – 120)
	Vigorous intensity activity MET-minutes/week	2400 (1200 – 4320)	1680 (480 – 3840)	1920 (720 – 4320)
Moderate-intensity Physical activity	Any moderate-intensity PA for ≥10 minutes	15 (79%)	53 (79%)	68 (79%)
	Time spent doing moderate- intensity PA per day in mins	75 (30 – 120)	60 (30 – 90)	60 (30 – 90)
	Moderate intensity activity MET-minutes/week	1440 (480 – 1680)	720 (480 – 1200)	720 (480 – 1440)
Active Travel	Walking or cycling for ≥10 minutes continuously for travel	16 (84%)	45 (67%)	61 (71%)
	Time spent walking or cycling on a typical day in minutes	40 (30 – 60)	30 (30 – 60)	35 (30 – 60)
	Walking MET-minutes/week	610.5 (396 – 1386)	495 (247.5 – 990)	528 (297 – 990)
Total physical activity MET-minutes/week		2504.25 (690 – 7146)	1173 (495 – 2826)	1215 (495 – 3348)
Insufficient physical activity (achieved < 600 MET-minutes per week)		4 (21%)	23 (34%)	27 (31%)
High physical activity (≥3000 MET minutes per week)		8 (42%)	15 (22%)	23 (27%)
Sedentary behaviour (≥3 hours of sedentary time per day)		10 (53%)	32 (48%)	42 (49%)
Dietary Behaviour (n= 82)				
Fruits consumption *(p= 0.028)*	Never	0	2 (3%)	2 (2%)
	Once a week / less than once a week	4 (21%)	27 (43%)	31 (28%)
	2 – 4 times a week	5 (26%)	15 (24%)	20 (24%)
	Frequently (5 – 6 times a week)	4 (21%)	2 (3%)	6 (7%)
	Daily or more than once daily	6 (32%)	17 (27%)	23 (2%)
Vegetables consumption	Never	0	4 (6%)	4 (5%)
	Once a week / less than once a week	3 (17%)	9 (14%)	12 (15%)
	2 - 4 times a week	1 (6%)	9 (14%)	10 (12%)
	Frequently (5 – 6 times a week)	6 (33%)	7 (11%)	13 (16%)
	Daily or more than once daily	8 (44%)	34 (54%)	42 (52%)
Wholegrain bread or cereal Consumption	Never	1 (5%)	4 (6%)	5 (6%)
	Once a week / less than once a week	5 (26%)	16 (25%)	21 (26%)

(n= 68)	2 – 4 times a week	2 (11%)	6 (10%)	8 (10%)
	Frequently (5 – 6 times a week)	3 (16%)	4 (6%)	7 (9%)
	Daily or more than once daily	5 (26%)	22 (35%)	27 (33%)
Daily consumption of sugar-sweetened beverages		5 (26%)	20 (30%)	25 (29%)
Daily consumption of deep-fried foods		3 (16%)	15 (22%)	18 (21%)
Daily consumption of fast foods		1 (5%)	12 (18%)	13 (15%)
Daily consumption of sweets & cakes		2 (11%)	25 (37%)	27 (31%)
Ate a meal prepared outside the home in the past week		10 (59%)	45 (73%)	55 (67%)
	Meals eaten outside the home in past week: (n= 55)	2 (1 – 10)	2 (2 – 3)	2 (2 – 4)
Breakfast consumption: number of days in the past week		5 (3 – 6)	5 (3 – 7)	5 (3 – 7)
Breakfast consumption	Skippers: ate breakfast 0 – 2 days/week	5 (23%)	13 (20%)	18 (21%)
	Semi-skippers: ate breakfast 3 – 4 days/week	5 (23%)	13 (20%)	18 (21%)
	Non-skippers: ate breakfast 5 – 7 days/week	12 (54%)	39 (60%)	51 (58%)
Overall General Nutrition Knowledge score percentage % (score /88) (95% CI)		40.3% (34.5 -46.1)	36.5% (34.0 - 38.9)	37.3% (35.1 - 39.6)
	1. Dietary recommendations (score/18)	44.2% (35.3 - 53.0)	42.5% (38.7 - 46.3)	42.9% (39.4 - 46.4)
	2. Food Groups (score/36)	40.4 (35.5 - 45.4)	37.1 (34.1 - 40.1)	37.9 (35.3 - 40.4)
	3. Healthy food choices (score/13)	36.8 (27.3 - 46.2)	30.5 (26.0 - 35.1)	31.9 (27.9 - 36.0)
	4. Diet, disease and weight management (score /21)	36.8 (28.2 - 45.3)	33.9 (30.6 - 37.1)	34.5 (31.4 - 37.6)

MET = Metabolic equivalent of task; n= number; % = percentage; PA = physical activity; p-value shown if significant at 5% level: $p < 0.05$.

TABLE 3: Physical Activity, Sedentary and Dietary Behaviour and Nutritional Knowledge by Age Group

Variable: Median (IQR) or n (%)	Description	15- 17 years: n=11 (13%)	18- 19 years: n= 23 (27%)	20- 21years: n= 23 (27%)	22- 24 years: n= 29 (34%)	Total: n= 86
Vigorous intensity Physical Activity	Prevalence of PA for ≥10 mins	8 (80%)	9 (39%)	11 (50%)	9 (31%)	37 (43%)
	Time spent per day in minutes	120 (30 – 240)	90 (30 – 120)	105 (30 – 180)	60 (30 – 60)	60 (30 – 120)
	MET-minutes/week	4800 (720 – 9600)	2160 (1200 – 2400)	2520 (960 – 4320)	1440 (480 – 1920)	1920 (720 – 4320)
Moderate-intensity Physical Activity	Prevalence of PA for ≥10 minutes	5 (50%)	17 (74%)	19 (86%)	25 (86%)	68 (79%)
	Time spent per day in mins	60 (30 – 60)	60 (40 – 120)	30 (30 – 120)	30 (30 – 60)	60 (30 – 90)
	MET-minutes/week	720 (360 – 720)	1440 (640 – 1680)	600 (420 – 1680)	600 (480 – 840)	720 (480 – 1440)
Active Travel Walking or cycling	Walking or cycling for ≥ 10 minutes	7 (70%)	19 (83%)	14 (64%)	20 (69%)	60 (71%)
	Time spent daily in mins	30 (30 – 120)	30 (30 – 60)	60 (30 – 60)	30 (30 – 60)	35 (30 – 60)
	Walking MET-minutes/week	495 (495 – 495)	693 (396 – 1386)	742.5 (495 – 1188)	495 (198 – 693)	528 (297 – 990)
Total physical activity MET-minutes/week		984 (280 – 5295)	2160 (800 – 3756)	1638.75 (420 – 6624)	876 (508.5 – 1878)	1215 (495 – 3348)
Insufficient physical activity (< 600 MET-mins per week)		5 (45%)	5 (22%)	7 (30%)	10 (34%)	27 (31%)
High physical activity (≥3000 MET mins per week)		3 (27%)	8 (35%)	9 (39%)	3 (10%)	23 (27%)
Sedentary behaviour (≥3 hours of sedentary time per day)		7 (70%)	9 (39%)	12 (54%)	14 (49%)	42 (49%)
Dietary Behaviour (n= 82)						
Fruits consumption	Never	0	0	0	2 (7%)	2 (2%)
	Once a week / less than once a week	5 (50%)	9 (39%)	10 (45%)	7 (26%)	31 (38%)
	2 – 4 times a week	2 (20%)	5 (22%)	4 (18%)	9 (33%)	20

						(24%)
	Frequently (5 – 6 times a week)	2 (20%)	0	3 (14%)	1 (4%)	6 (7%)
	Daily or more than once daily	1 (10%)	9 (39%)	5 (23%)	8 (30%)	23 (28%)
Vegetables consumption	Never	0	1 (4%)	1 (5%)	2 (7%)	4 (5%)
	Once a week / less than once a week	2 (20%)	5 (22%)	3 (14%)	2 (7%)	12 (15%)
	2 – 4 times a week	2 (20%)	1 (4%)	0	7 (265)	10 (12%)
	Frequently (5 – 6 times a week)	2 (20%)	4 (17%)	6 (29%)	1 (4%)	13 (16%)
	Daily or more than once daily	4 (40%)	12 (52%)	11 (52%)	15 (56%)	42 (52%)
Whole-grain bread or cereal consumption (n=68)	Never	0	1 (4%)	1 (5%)	3 (11%)	5 (6%)
	Once a week / less than once a week	5 (50%)	7 (30%)	5 (23%)	4 (15%)	21 (26%)
	2 – 4 times a week	2 (20%)	1 (4%)	1 (5%)	4 (15%)	8 (10%)
	Frequently (5 – 6 times a week)	1 (10%)	4 (17%)	1 (5%)	1 (4%)	7 (9%)
	Daily or more than once daily	1 (10%)	9 (39%)	7 (32%)	10 (37%)	27 (33%)
Daily consumption of sugar-sweetened beverages		3 (27%)	6 (26%)	9 (39%)	7 (24%)	25 (29%)
Daily consumption of deep-fried foods *(p= 0.031)*		1 (9%)	8 (35%)	5 (22%)	4 (14%)	18 (21%)
Daily consumption of fast foods		2 (18%)	6 (26%)	2 (9%)	3 (10%)	13 (15%)
Daily consumption of sweets & cakes		4 (36%)	9 (39%)	6 (26%)	8 (28%)	27 (31%)
Dietary Behaviour (n= 82)						
Ate meal prepared outside the home in past week		5 (50%)	14 (64%)	15 (68%)	21 (78%)	55 (67%)
	Meals eaten outside the home in past week: (n= 55)	2 (1 – 3)	2 (2 – 4)	2 (2 – 4)	2 (2 – 3)	2 (2 – 4)
Breakfast consumption	Skippers: ate breakfast 0 – 2 days/week	2 (20%)	7 (30%)	3 (14%)	7 (26%)	19 (23%)
	Semi-skippers: ate	1 (10%)	4 (17%)	6 (27%)	3 (11%)	14

	breakfast 3 – 4 days/week					(17%)
	Non-skippers: ate breakfast 5 – 7 days/week	7 (70%)	12 (52%)	13 (59%)	17 (63%)	49 (60%)
Overall General Nutrition Knowledge score percentage (score /88) mean (95% CI)		35.6 (28.4 - 42.9)	38.1 (34.1 - 42.1)	34.3 (28.9 - 39.6)	39.6 (35.7 - 43.4)	37.3 (35.1 - 39.6)
	1. Dietary recommendations (score/18)	39.9 (27.8 - 52.0)	46.1 (39.8 - 52.4)	40.2 (32.3 - 48.1)	43.4 (37.5 - 49.3)	42.9 (39.4 - 46.4)
	2. Food Groups (score/36)	37.6 (31.6 - 43.7)	37.4 (32.3 - 42.5)	35.0 (29.7 - 40.3)	40.4 (35.5 - 45.4)	37.9 (35.3 - 40.4)
	3. Healthy Food choices (score/13)	33.6 (21.5 - 45.6)	35.1 (28.4 - 41.8)	27.7 (17.8 - 37.6)	31.6 (24.2 - 39.0)	31.9 (27.9 – 36.0)
	4. Diet, disease relationship (score/21)	29.9 (20.6 - 39.2)	34.4 (29.4 - 39.3)	30.2 (23.3 - 37.1)	39.7 (34.0 - 45.3)	34.5 (31.4 - 37.6)

n= number; % = percentage; mins= minutes; PA = physical activity; MET = Metabolic equivalent of task;
p-value from Kruskal Wallis test shown if significant at 5% level: $p < 0.05$.

TABLE 4: Comorbidities and Pre-existing diagnoses by Gender

Variable: median (IQR) or n (%) or proportion [95% CI]		Male: n= 22	Female: n= 70	Total n= 92	p-value[1]
Self-reported pre-existing diagnosis: prop [95% CI] [2]		0.45 [0.24 - 0.68]	0.31 [0.21 - 0.44]	0.35 [0.25 - 0.45]	0.228
	Tuberculosis	0.32 [0.14 - 0.55]	0.2 [0.11 - 0.31]	0.23 [0.15 - 0.33]	0.229
	Depression or Anxiety	0.14 [0.029 - 0.35]	0.071 [0.024 - 0.16]	0.087 [0.038 - 0.16]	0.332
	Asthma	0.045 [0.0012 - 0.23]	0.043 [0.0089 - 0.12]	0.043 [0.012 - 0.11]	0.946
	High Blood Pressure	0 [0 - 0.15]	0.043 [0.089 - 0.12]	0.033 [0.0068 - 0.092]	0.327
	Diabetes	0 [0 - 0.15]	0.014 [0.00036 - 0.077]	0.011 [0.00028 - 0.061]	0.576
Respiratory Symptoms over past 3 months (n= 89): prop [95% CI]		0.10 [0.012 - 0.30]	0.13 [0.062 - 0.24]	0.12 [0.063 - 0.21]	0.651
Diabetes Symptoms over past 3 months: prop [95% CI]		0.29 [0.11 - 0.52]	0.24 [0.14 - 0.35]	0.25 [0.16 - 0.35]	0.640
Family history of diabetes: prop [95% CI]		0.38 [0.18 - 0.62]	0.24 [0.14 - 0.35]	0.27 [0.18 - 0.37]	0.189
Random Blood Glucose in mmol/l (n=31) [3] median (IQR)		3.7 (0.75 - 4.95)	4.8 (4.0 - 5.5)	4.7 (3.1- 5.3)	0.1672
CESD-10 Depression Score (n=82) median (IQR)		8 (4 – 9)	10 (6 – 14)	9 (6 – 14)	0.055
	Significant depression (CESD ≥10): prop [95% CI]	0.19 [0.054 - 0.42]	0.51 [0.38 - 0.64]	0.43 [0.32 - 0.54]	0.011
Kessler Psychological Distress Score (K10) (n= 85) median (IQR)		17 (13 - 23)	19 (13 – 25)	19 (13 – 25)	0.959
Categories n (%)	Mentally well (K10 <20)	12 (57%)	35 (55%)	47 (55%)	0.407
	Mild distress (K10 20-24)	4 (19%)	10 (16%)	14 (16%)	
	Moderate distress (K10 25-29)	2 (10%)	15 (23%)	17 (20%)	
	Severe distress (K10 ≥30)	3 (14%)	4 (6%)	7 (8%)	
Measured Clinical Signs					
BMI in kg/m^2 ; median (IQR)		21.0 (19.1 - 22.6)	23.3 (20.2 - 27.2)	22.8 (19.9 - 26.2)	0.0102
Categories n (%)	Underweight (BMI<18.5)	5 (23%)	5 (7%)	10 (11%)	0.032
	Normal weight (18.5 ≤ BMI< 25)	14 (64%)	33 (49%)	47(53%)	
	Overweight (25≤ BMI< 30)	3 (14%)	19 (28%)	22 (25%)	
	Obese (BMI ≥ 30)	0	10 (15%)	10 (11%)	

Waist circumference (WC) in cm; median (IQR)		74 (71.5 – 81.0)	78.4 (71.5 – 88.0)	76 (71.5 – 87)	0.2135
	Abdominal obesity[4]	1 (5%)	17 (24%)	18 (20%)	0.049
Hip circumference in cm; median (IQR)		87.5 (84 - 94)	97.5 (90.5-108)	95 (86.75-106.5)	0.0011
Waist-hip ratio (WHR) median (IQR)		0.85 (0.82-0.87)	0.82 (0.77 - 0.85)	0.82 (0.78 - 0.87)	0.0265
Waist-to-height ratio (WHtR) median (IQR)		0.43 (0.42 - 0.48)	0.49 (0.45 - 0.56)	0.48 (0.44 - 0.54)	0.0006
Central obesity	WHR > 0.85 in females and > 0.95 in males	0	19 (27%)	19 (21%)	0.007
	WHtR > 0.5	3 (14%)	31 (44%)	34 (37%)	0.020
Blood Pressure in mmHg (Systolic/ Diastolic Blood Pressure) median (IQR)		119.5/74.75 (110/66.5 – 131.5/80.5)	115/74 (109.5/68.5 – 124.5/78)	117.5/74.25 (109.5/68 – 125.5/79)	0.9635 0.2097
Categories n (%)	Normal BP: SBP < 130 & DBP < 85	13 (59%)	56 (80%)	69 (75%)	0.056
	Elevated BP: SBP 130–139 or DBP 85 – 89	6 (27%)	12 (17%)	18 (20%)	
	Hypertension: SBP 140–159/ DBP 90 – 99	3 (14%)	2 (3%)	5 (5%)	

[1] Wilcoxon rank-sum test p-value for continuous variables and Pearson χ^2 test for categorical variables;
[2] Proportion and Binomial exact 95% Confidence interval;
[3] Blood glucose measured only if had one or more symptoms of diabetes and OR family history;
[4] Abdominal obesity: WC > 88cm in females, WC > 102 cm in males.

TABLE 5: Comorbidities and Pre-existing diagnoses by Age Group

Variable: median (IQR) or n (%)		**15 - 17 years: n=14 (15%)**	**18 - 19 years: n= 23 (25%)**	**20 - 21 years: n= 26 (28%)**	**22 - 24 years: n= 29 (32%)**	**Total: n= 92**
Self-reported past diagnosis: n (%)	1 (7%)		9 (39%)	9 (35%)	13 (45%)	32 (35%)
	Tuberculosis	1 (7%)	5 (22%)	6 (23%)	9 (31%)	21 (23%)
	Depression or Anxiety	0	4 (17%)	2 (8%)	2 (7%)	8 (9%)
	Asthma	0	2 (9%)	2 (8%)	0	4 (4%)
	High Blood Pressure	0	0	1 (4%)	2 (7%)	3 (3%)
	Diabetes	0	1 (11%)	0	0	1 (3%)
Respiratory Symptoms over the past 3 months (n= 89)		4 (29%)	4 (17%)	2 (8%)	1 (3%)	11 (12%)
Diabetes Symptoms over past 3 months *(p= 0.047)*[1]		**6 (46%)**	**8 (35%)**	**4 (16%)**	**4 (14%)**	**23 (25%)**
Family history of diabetes		6 (46%)	7 (30%)	4 (16%)	7 (24%)	24 (27%)
Random Blood Glucose in mmol/l (n=31) [2] median (IQR)		3.65 (1 – 4.9)	4.4 (2.75 – 5.5)	5 (2.4 – 5.45)	5.2 (4.7 – 5.5)	4.7(3.1 – 5.3)
CESD-10 Depression Score (n=81) median (IQR)		9 (6 – 12)	10.5 (7.5 – 14)	9 (7.5 – 13.5)	8.5 (6 – 12)	9 (6 – 14)
	Significant depression (CESD ≥10)	5 (38%)	12 (60%)	8 (33%)	10 (42%)	35 (43%)
Kessler Distress Score (K10) (n= 85) median (IQR)		15 (14 – 24)	19 (15 – 25)	18 (12 – 25)	18.5 (13 – 25)	19 (13 – 25)
Categories n (%)	Mentally well (K10 <20)	7 (54%)	12 (55%)	13 (54%)	15 (58%)	47 (55%)
	Mild distress (K10 20-24)	3 (23%)	3 (14%)	5 (21%)	3 (12%)	14 (16%)
	Moderate distress (K10 25-29)	1 (8%)	5 (23%)	4 (17%)	7 (27%)	17 (20%)
	Severe distress (K10 ≥30)	2 (15%)	2 (9%)	2 (8%)	1 (4%)	7 (8%)
Measured Clinical Signs						
BMI in kg/m^2 (n= 87); median (IQR)		20.8 (19.5 – 24.1)	23.2 (19.3 - 26.4)	22.1 (20.6 - 25.9)	24.2 (20.2 – 27.1)	22.8 (19.9 - 26.2)
Categories n (%)	Underweight (BMI<18.5)	2 (14%)	4 (19%)	1 (4%)	3 (10%)	10 (11%)
	Normal weight (18.5 ≤ BMI< 25)	9 (64%)	8 (38%)	15 (60%)	15 (52%)	47 (53%)
	Overweight (25≤ BMI< 30)	1 (7%)	7 (33%)	6 (24%)	8 (28%)	22 (25%)
	Obese (BMI ≥ 30)	2 (14%)	2 (10%)	3 (12%)	3 (10%)	10 (11%)
Waist circumference (WC) in cm; median		74.5 (71 –	74.6 (67.5	78.8 (73 –	79 (71 –	76 (71.5 –

(IQR)		76)	– 88)	85)	88)	87)
	Abdominal obesity[3]	2 (15%)	5 (23%)	4 (12%)	7 (24%)	17 (19%)
Hip circumference in cm; median (IQR)		91 (83.5 – 104)	90.5 (84.8 – 107)	96.7 (93 – 107)	95 (90 – 105)	95 (86.5 – 106)
Waist-hip ratio (WHR); median (IQR)		0.83 (0.79 - 0.87)	0.83 (0.77 - 0.87)	0.82 (0.78 - 0.85)	0.82 (0.79 - 0.87)	0.82 (0.78 - 0.87)
Waist-to-height ratio (WHtR); median (IQR)		0.47 (0.43 - 0.48)	0.45 (0.43 - 0.53)	0.48 (0.44 - 0.52)	0.49 (0.44 - 0.57)	0.48 (0.44 - 0.54)
Central obesity	WHR > 0.85 in female and > 0.95 in male	3 (23%)	5 (23%)	3 (8%)	8 (28%)	18 (20%)
	WHtR > 0.5	2 (14%)	9 (39%)	11 (42%)	12 (41%)	34 (37%)
Systolic Blood Pressure in mmHg; median (IQR)		117.5 (112 – 125.5)	118 (108.5 – 124.5)	118 (111 – 131)	117 (107.5 – 123.5)	117.5 (109.5– 125.5)
Diastolic Blood Pressure in mmHg; median (IQR)		73.5 (66.5 – 77)	75 (67 – 76.5)	76 (71 – 80)	74 (68.5 – 80)	74.25 (68 – 79.5)
Categories n (%)	Normal BP: SBP<130 & DBP<85	11 (79%)	18 (78%)	18 (69%)	22 (76%)	69 (75%)
	Elevated BP: SBP 130–139 or DBP 85–89	3 (21%)	4 (17%)	6 (23%)	5 (17%)	18 (20%)
	Hypertension: SBP 140–159/ DBP 90- 99	0	1 (4%)	2 (8%)	2 (7%)	5 (5 %)

[1] P-value derived from Fisher's exact text;
[2] Blood glucose measured only if had one or more symptoms of diabetes and OR family history;
[3] Abdominal obesity: WC >88cm female, WC >102 cm in male.

Figures

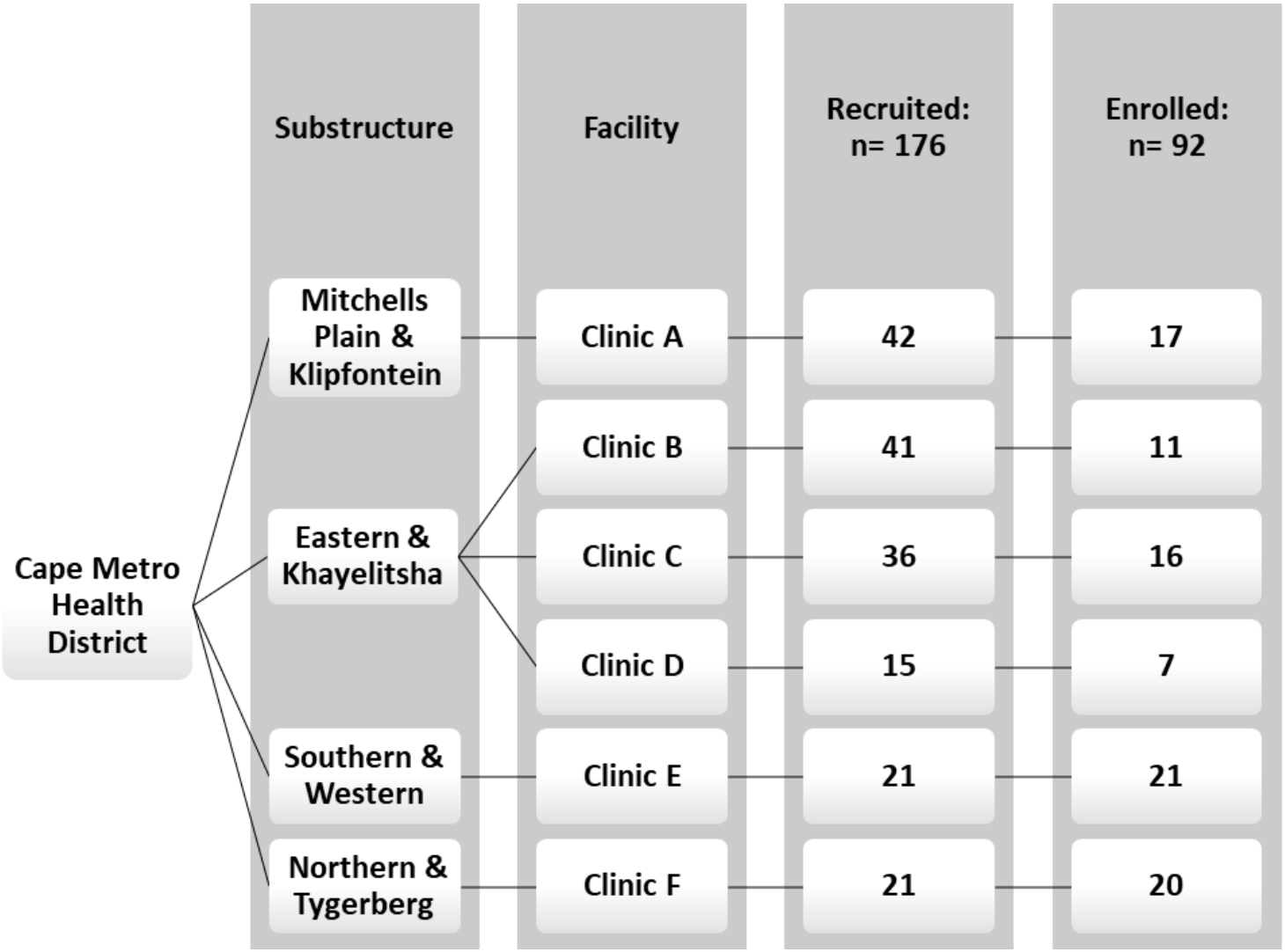

Figure 1

Participant Recruitment and enrolment at respective facilities

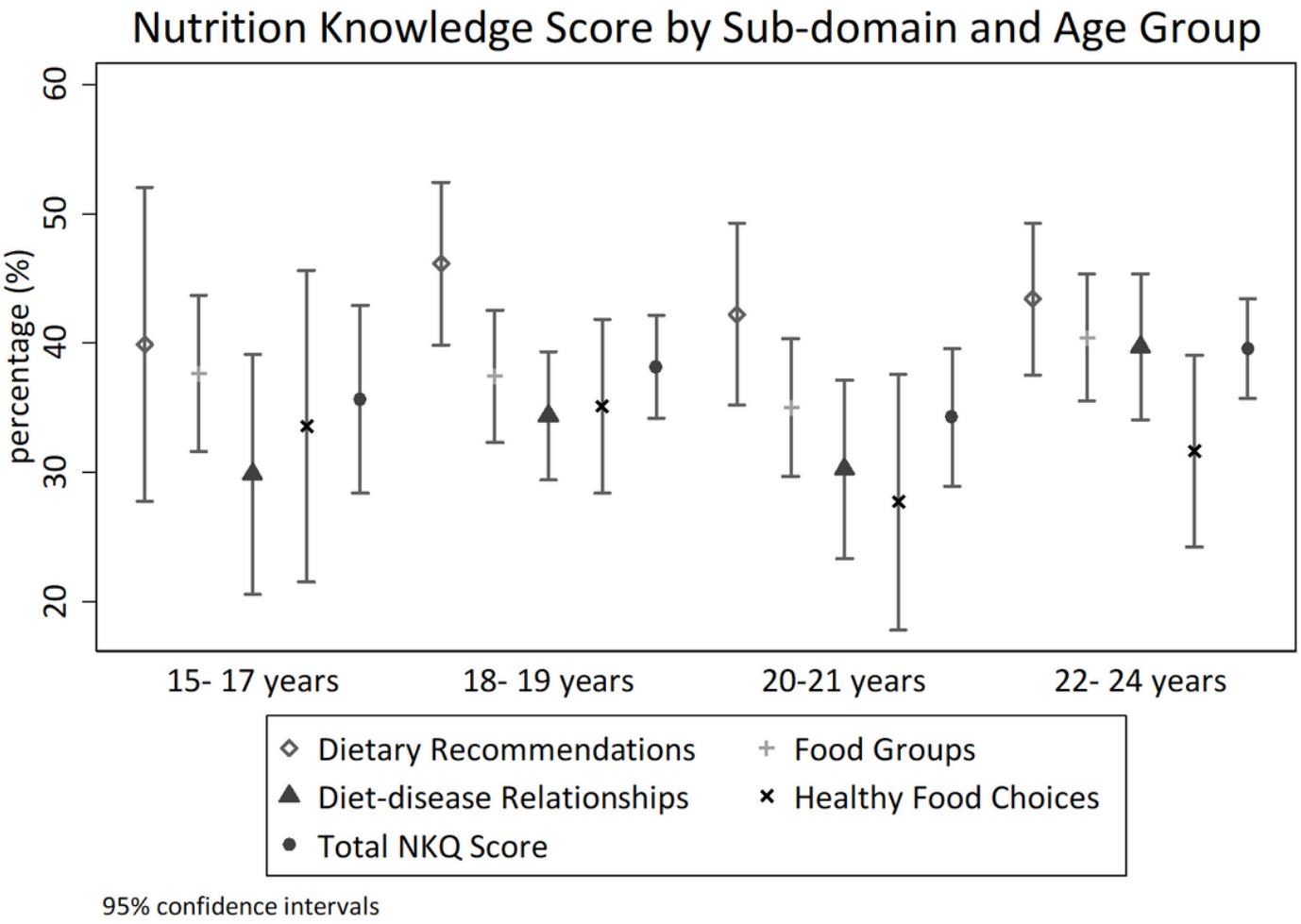

Figure 2

Nutrition Knowledge Score by Sub-domain and Age Group

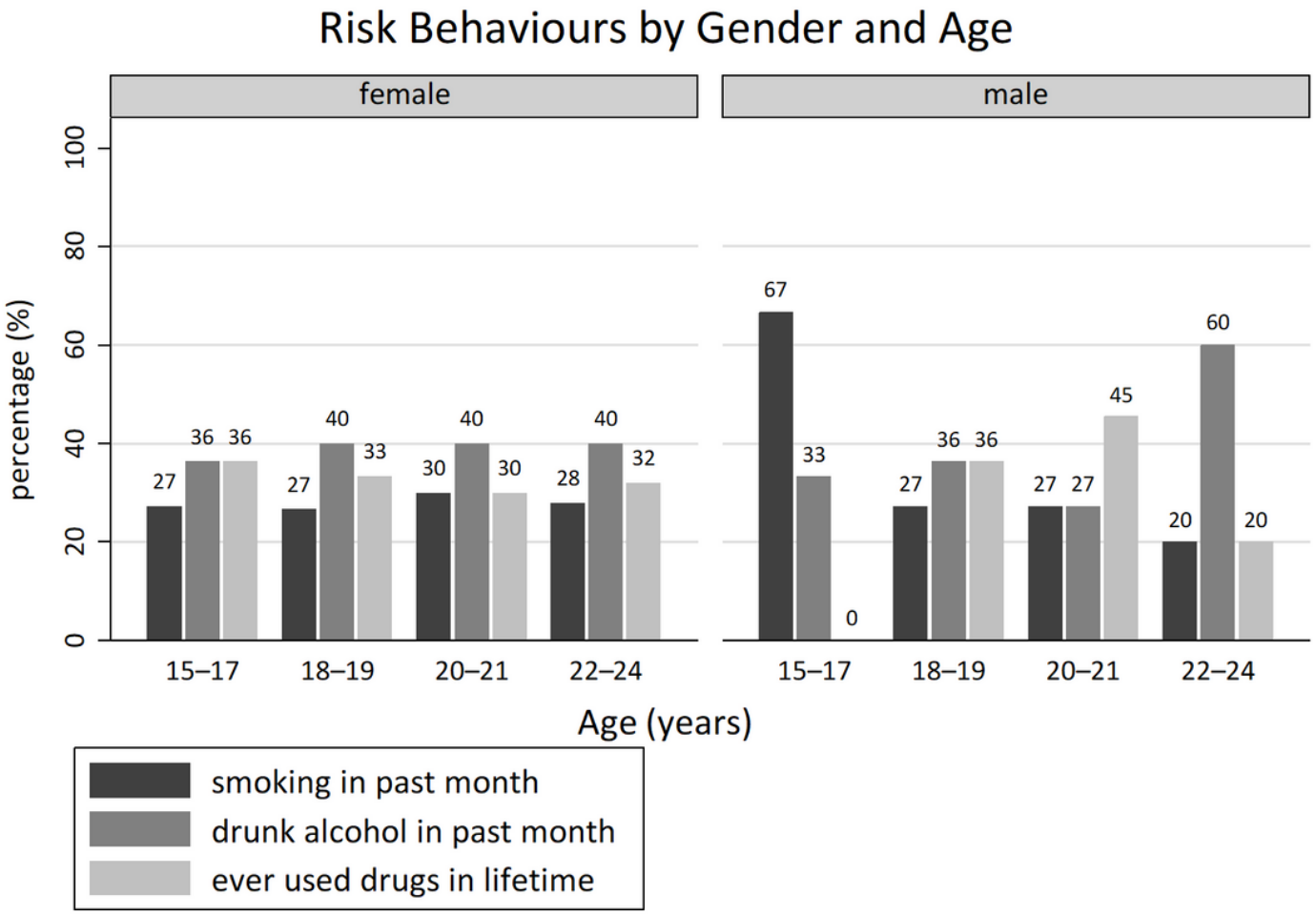

Figure 3

Current smoking, alcohol consumption, and lifetime substance use by Gender and Age Group

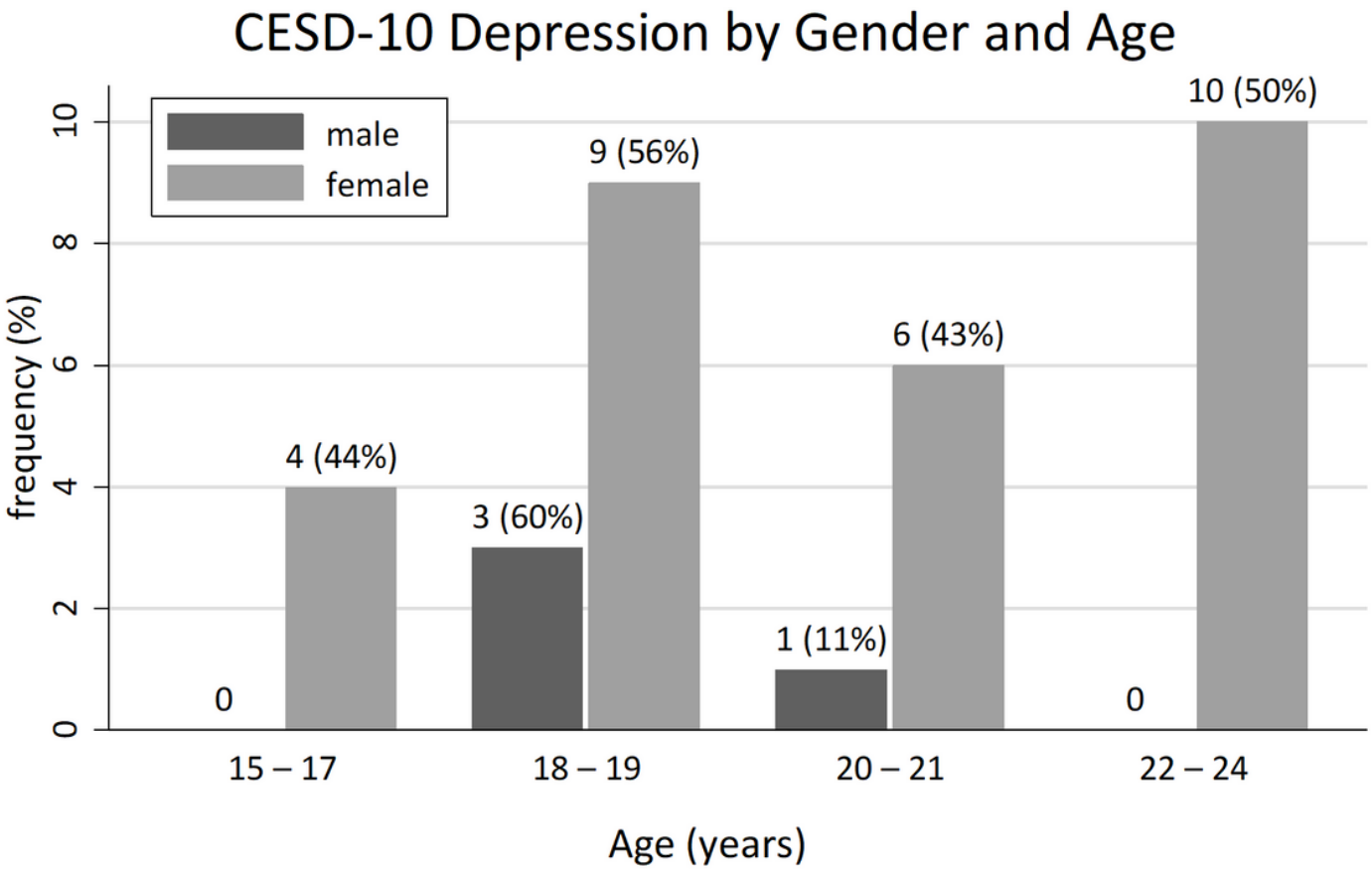

Figure 4

Mental Health Status by Gender and Age Group Bar represents proportion (%) with significant depression (CESD score ≥10) by gender in each age group.

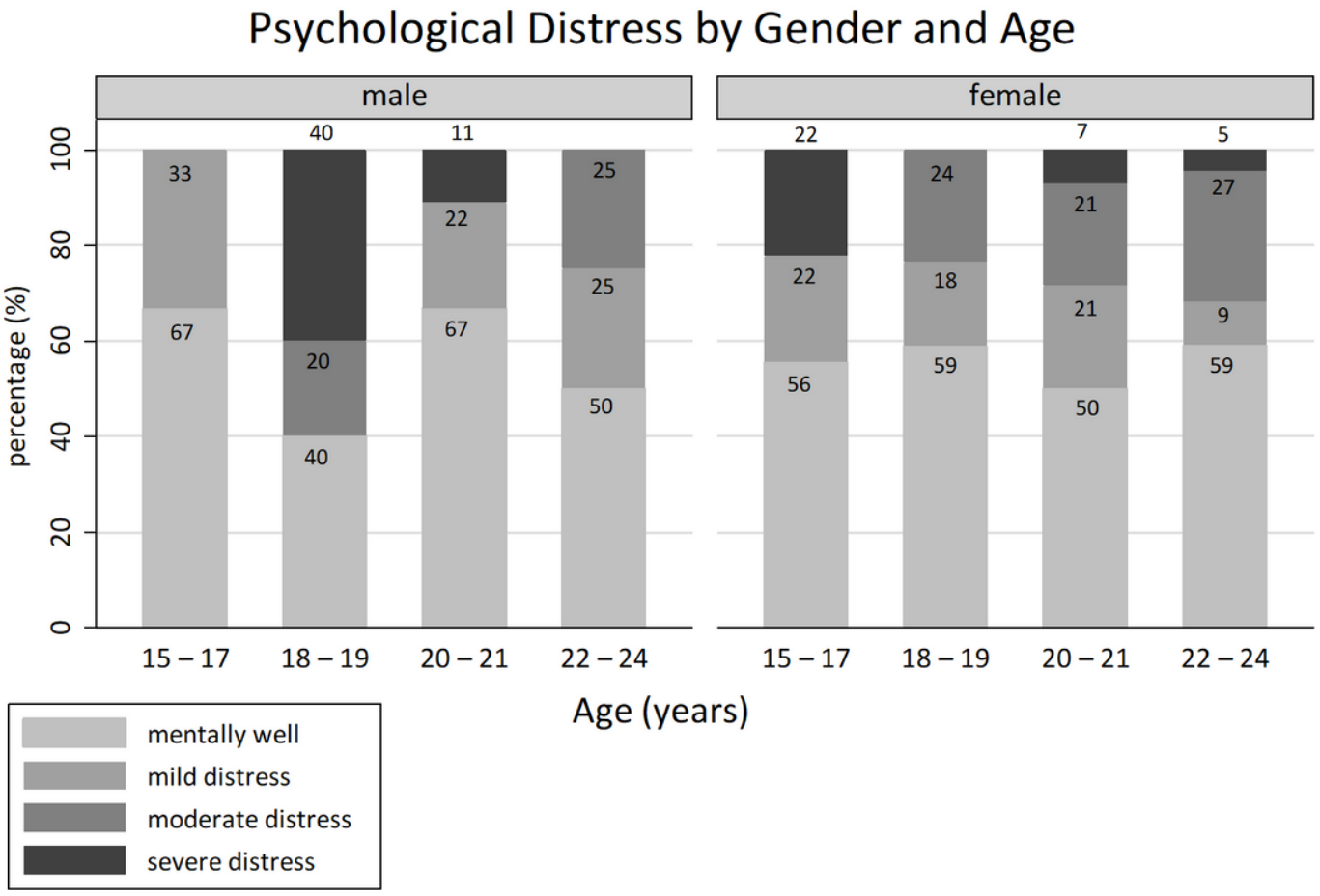

Figure 5

Severity of Psychological Distress by Gender and Age Group Psychological distress according to Kessler (K10) Distress Scale. Bars represent severity of distress (%) by gender and age group

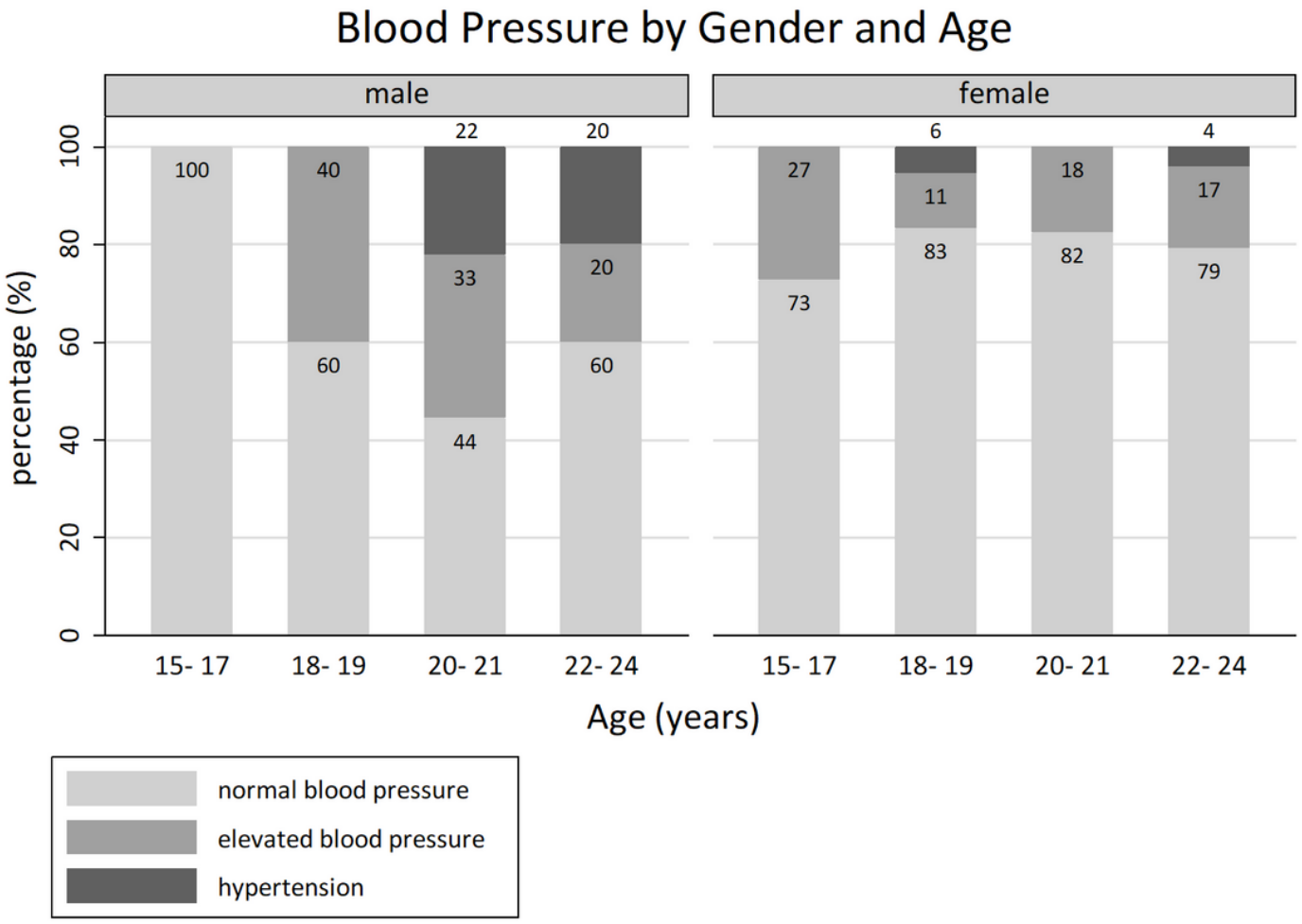

Figure 6

Blood Pressure Category by Gender and Age Group

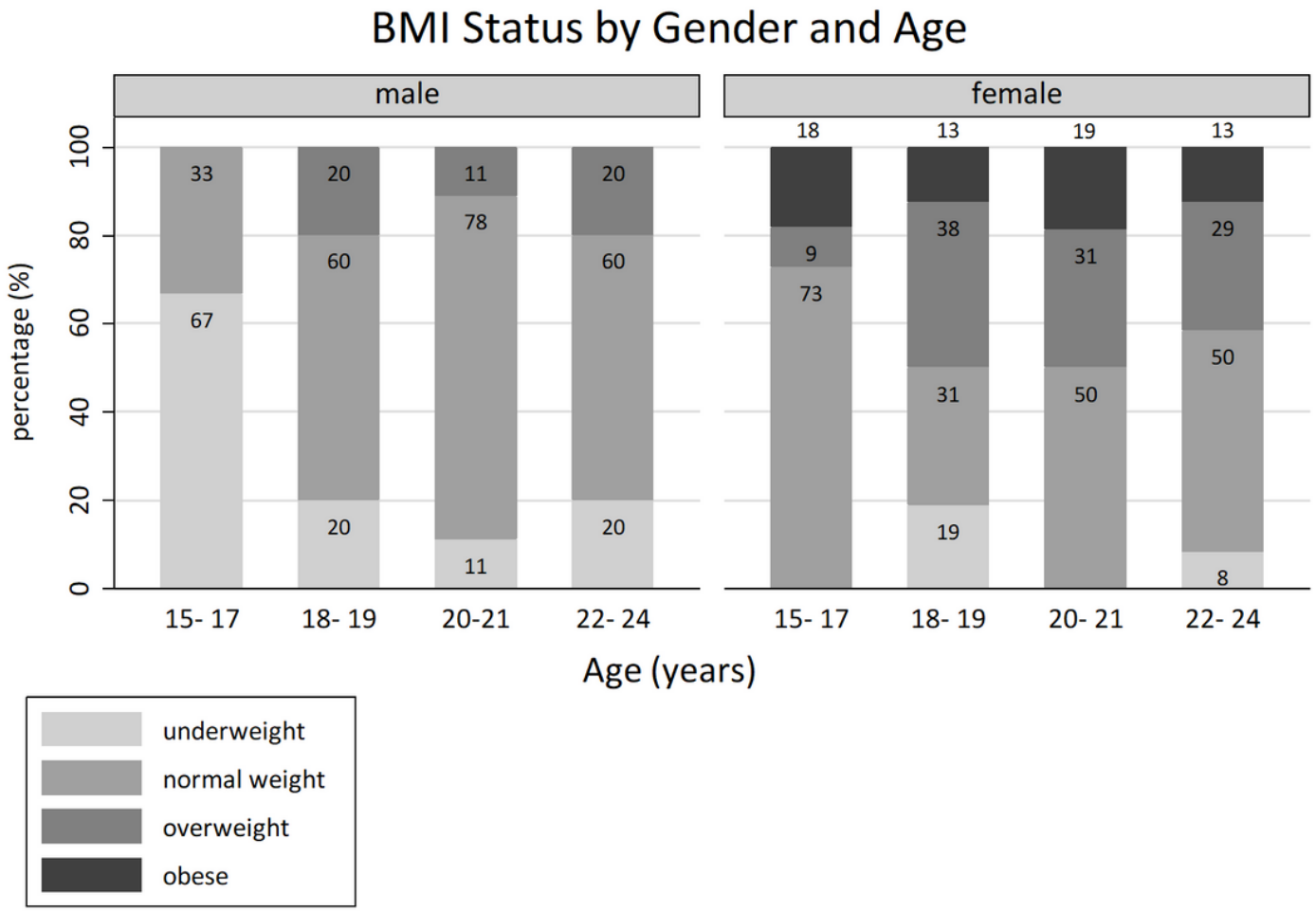

Figure 7

Weight Status by Gender and Age Group