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Welfare Impacts of Drought Adaptation Strategies in John Taolo Gaetsewe District, Northern Cape Province, South Africa

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ABSTRACT

Drought is a global problem that presents a negative impact on the welfare of millions of people in both industrialized and developing nations. In South Africa, poor rural households, who depend on rain-fed subsistence agriculture for their livelihoods are the most susceptible to drought, and have the least ability to absorb its impacts. The primary goal of this study was to analyse the effects of drought adaptation strategies on rural households' welfare and to compute the welfare enhancement impacts that are associated with each adaptation method. The study was conducted in John Taolo Gaetsewe district, Northern Cape province. Multistage sampling technique was used to sample 360 rural households, who were affected by drought. The results showed that the average age of households' heads was 52 years. Only 41% of the households' heads had an education level between Grades 8 and 12, and about 63% were male. Average farming experience was 7.67 years and pensioners made up about 47%. Also, 65% of households' heads depended on government assistance, while 85% lacked access to formal credit. The 2SLS results showed that household income, household size, pension, grant, and use of crop diversification significantly influenced per capita consumption expenditure. The results showed that average treatment effect (ATE) from crop diversification was R497.16 and statistically significant ($p<0.05$). It was concluded that many drought adaptation methods are not influencing households' welfare, and efforts to promote adaptation should focus on crop diversification with specific assistance given to social grant holders.

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INTRODUCTION

Drought is generally defined as a prolonged period of water shortage, lasting months, or years, during which precipitation is below the annual average (Nairizi, 2017). It is one of the most expensive natural catastrophes (Huang et al., 2017), due to the negative effects it has on commercial activities, tourism, agricultural production, and rural/urban infrastructure. Droughts are the global consequences of climate change, and their negative impacts on households' welfare cannot be overemphasized [Global Assessment Report on Disaster Risk Reduction (GAR), 2011]. In the past 50 years, droughts are serious environmental issue in Africa, contributing to asset depletion, environmental damages, poverty, unemployment, and forced migration (Shiferaw *et al*., 2014). In Sub-Saharan Africa (SSA), droughts are perennial occurrences with significant impacts on farming and other rural livelihoods. It is a fundamental income shock confronting farmer with significant welfare impacts (Shiferaw *et al*., 2014; Lottering *et al*., 2020). However, because of some difficulties in accessing some hydro-meteorological variables (Umdale *et al*., 2014), very little empirical evidence exists on the impacts of drought in SSA, particularly in South Africa.

It should be emphasized that in recent years, severe droughts have ravaged several parts of the world, particularly African countries, with some economic consequences. These regions include Angola, Namibia, Kenya, and South Africa, to mention a few. Specifically, Angola is among the African countries that recently experienced drought (Phiri, 2021). This problem resulted in dwindling water supplies, which had significant impacts on crops, with potential production losses of up to 40%, and serious risk on animal survival (Prates, 2021). In Namibia, approximately 430,000 people faced hunger in 2020 due to the most severe drought that the country ever experienced (Integrated Food Security Phase Classification, 2020). Like most of the other African countries, when it comes to drought and its severe welfare effects, Kenya is also not exempted. In September 2021, the country declared drought as a national disaster after experiencing three consecutive poor rainy seasons (International Federation of Red Cross and Red Crescent Societies (IFRC), 2019). In like manner, South Africa has been ranked by the World-Wide Fund for Nature (2018) as the 30th driest country in the world. With annual rainfall ranging from more than 1500 mm in the east to less than 100 mm in the west, South Africa is a semi-arid nation with 450 millimetres average annual rainfall, which is much less than the global average of 860 millimetres (Botai *et al.,* 2018).

Within the foregoing context, the main goal of this study is to analyse how adaptation strategies against droughts affect rural households' welfare in Northern Cape, which is among the three provinces that were designated as national disaster zones in 2018 (Tandwa, 2018). The Northern Cape province experiences annual rainfall ranging from 50 to 400 mm, which is less than the 450 mm average annual rainfall of the nation (Botai *et al*., 2021). There has been no improvement in rainfall volume and distribution in the Northern Cape province since 2015 (Ramafoko *et al*., 2021). According to Jordaan (2012), drought in the Northern Cape province was hydrologically caused by below-average rainfall with exacerbating impacts from above average temperature and human activities.

Income and consumption are frequent, direct, and observable indices of welfare level following exposure to exogenous environmental shocks like drought (Skoufias and Vinha, 2013). Therefore, if households are unable to maintain their current level of consumption perfectly when their income is impacted by droughts, they must utilize their savings. Households may also change investment priorities because of limited economic resources (Shah and Steinberg, 2015). The ability to adapt and their impacts on households' welfare will be influenced by a variety of economic, social, institutional, political, and biophysical factors, including dynamic climatic and non-climatic processes that both support and limit adaptive behaviour (Adger *et al*., 2012).

Effective adaptation is dependent on the individual or capacity of groups for adaptation, access to human, economic, social, and institutional resources, as well as natural resources, and their potential to mobilize those resources in response to drought (Yung *et al*., 2015). Successful adaptation strategies will enhance people's adaptive capacity through education, employment and with support of social capital (Sozbilir, 2018). It is through these strategies that people will attempt to alleviate or avoid the negative impacts of environmental changes such as drought.

Therefore, the aim of the study was to identify the types of impact that drought had on the welfare of rural households, to determine which adaptation strategies were effectively adopted by rural households and to also determine what impact these adopted adaptation strategies made on improving the welfare of rural households. The decision to conduct the current study was driven by the knowledge that there were a few studies that explored how drought adaptation strategies affected the welfare of rural households in terms of consumption expenditure. As a result, this work tried to fill a very important knowledge gap.

MATERIALS AND METHODS

Description and selection of the study area

This study was conducted in the John Taolo Gaetsewe District (JTGD), which is one of the five districts in Northern Cape province. It is located between latitude 26^{o}07' and 27^{o}58' South and longitude 21^{o}46'and 24^{o}06' East. This district municipality is of category C, and shares borders with Botswana to the west. The composition of the district is largely rural, with villages accounting for about 80% of its 186 towns and settlements. The district comprises of three local municipalities, which are Gamagara, Ga-Segonyana, and Joe Morolong (Municipalities of South Africa, 2019). There are 242264 people living there in total, giving the area around 21322 km^2 and a population density of 9 persons per km^2 (Statistics South Africa Community Survey, 2016).

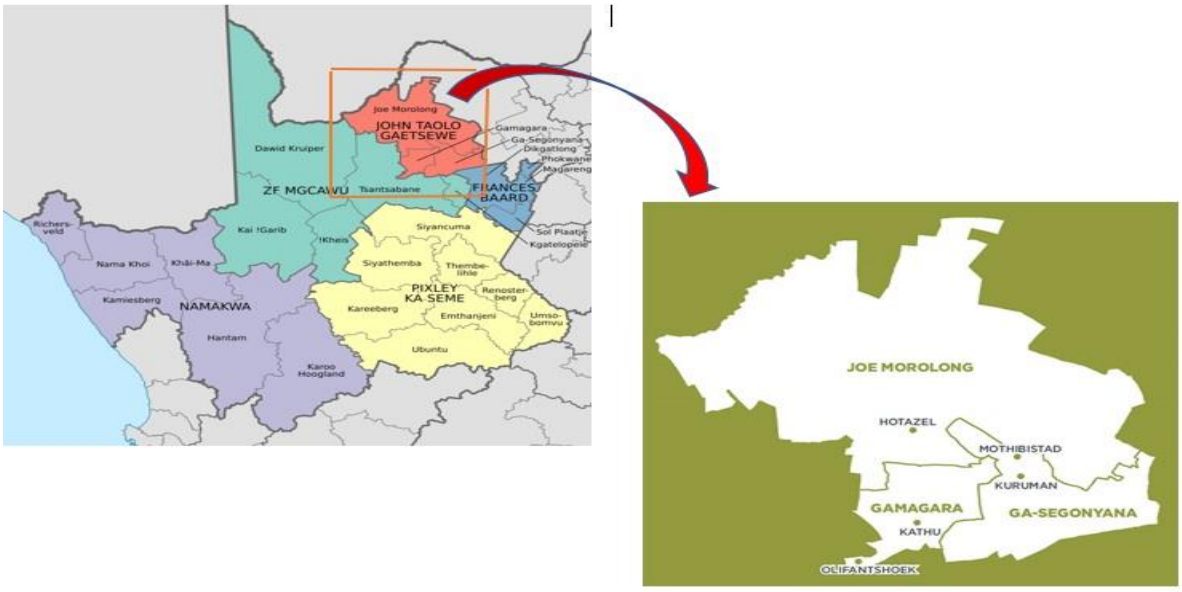

Figure 1. Map of John Taolo Gaetsewe district showing all three local municipalities

Source: Municipalities of South Africa (2019).

Data and Sampling Procedures

This study used primary data which were collected using multistage sampling technique. At the first stage, we selected the Northern Cape province purposively due to its high vulnerability to drought. The second stage involved a random selection of JTGD among the three most drought prone districts - Pixely Ka Seme, John Taolo Gaetsewe and Namakwa (John Taolo Gaetsewe District Municipality, 2016). The third stage involved selection of all the three local municipalities (Gamaraga, Ga-Segonyane and Joe Morolong) of the JTGD. In the final stage, the villages in each of the local municipalities were listed and randomly selected by the researcher for sampling. Household heads or adult members of the households were the respondents. According to Statistics South Africa Community Survey (2016), JTGD had a total number 72310 households of which 13 910 households were in rural areas. The sample size was derived from the 13910 rural households using the Raosoft sample size calculator. The sample size was calculated as:

$$SS = Z^2 \times p \times (1 - p) / C^2 \quad .1$$

where, SS = sample size, Z^2 = Z-value (e.g 1.96 for a 95% confidence interval), p = the % age of occurrence of a state of a condition, C^2 = confidence interval was 0.05 (5%). Therefore, the sample size was estimated as 374. However, due to COVID-19 restrictions, only 360 questionnaires were successfully interviewed, implying 96.26% response rate.

Data Analysis

Two-Stage Least Squares (2SLS)

A two-stage least square regression was used to analyse the effects of drought adaptation strategies on consumption expenditure (welfare) of rural households in the study area due to the potential endogeneity of households' incomes**.** In this study, per capita consumption expenditure was used as an indicator of welfare. This is because consumption is a better indicator to realistically measure welfare (Agency for Statistics of Bosnia and Herzegovina, 2017). Additionally, since the poor tend to spend somewhat consistently on a small number of well-known things, expenditure may be better measured than income, which might fluctuate and be unpredictable. People also do not easily disclose their incomes, which makes data collected inaccurate (Marotta and Yemtsov, 2010). Therefore, the study made use of per capita consumption expenditure as the dependent variable. Drought adaptation strategies were included as dummy variable coded as 1 for users and 0 otherwise. When using the two-stage least squares (2SLS) method, instrumental variables are to be used to estimate a casual effect and they must be highly correlated with endogenous regressor (income) but not correlated with the dependent variable (Cliff and Billy, 2017). The estimated model can be stated as:

$$Y_i = \beta + \pi X_i + \sum_{j=1}^{11} \theta_j Z_{ij} + \sum_{r=1}^{5} \sigma_r M_{is} + \epsilon_i \quad .2$$

$$X_i = \alpha + \sum_{s=1}^{4} \rho_s K_{is} + \sum_{j=1}^{11} \gamma_j Z_{ij} + \sum_{r=1}^{5} \pi_r M_{is} + \varepsilon_i \quad .3$$

The first stage involved estimation of equation 3 to generate estimated values of the endogenous regressor. The estimated values are then included in the second stage where we estimated the parameters of the variables in equation 2. In equation 2, Y_i is the per capita expenditure computed as total expenditure divided by household size. X_i is the total monthly income (Rands) which is suspected to be endogenous. Therefore, we included four instrumental variables which are age (years), years of education, formal non-farm

employment (yes=1, 0 otherwise), and self-non-farm employment (yes=1, 0 otherwise) to estimate it as shown in equation 3. Z_{ij} is a vector of other demographic variables, which are gender (female =1, 0 otherwise), household size, married (yes = 1, 0 otherwise), divorced (yes = 1, 0 otherwise), widow (yes = 1, 0 otherwise), cohabitating (yes = 1, 0 otherwise), farming experience, access to loan (yes = 1, 0 otherwise), pension income (yes = 1, 0 otherwise), social grant (yes = 1, 0 otherwise), and savings (yes = 1, 0 otherwise). The M_{is} are the included drought adaptation strategies, estimated as dummy variables and include crop diversification (yes = 1, 0 otherwise), livestock diversification (yes = 1, 0 otherwise), rainwater harvesting (yes = 1, 0 otherwise), drought tolerant crop (yes = 1, 0 otherwise), and crop rotation (yes = 1, 0 otherwise). β, π, $\theta_j, and\ \sigma_r$ are estimated structural parameters, while α, ρ_s, γ_j, and π_r are the estimated reduced parameters. ϵ_i and ε_i are the stochastic error terms.

Propensity score matching (PSM)

PSM was used to calculate the welfare impacts of different adaptation strategies. A dummy variable for adoption of adaptation strategy was used, which was coded as D = 1 for adopters and zero if otherwise. PSM estimates the average treatment effect (ATE) and average treatment effect on the treated (ATET) of adoption of strategies on the welfare of rural households. Households who adopted adaptation strategies (treatment group) were matched with those who did not adopt any adaptation strategies (control group). The idea is to match each adopter with an otherwise identical non-adopter on the basis of similarity in the observed data. Therefore, let Δ = Y_1- Y_0 where $Y_1$is the average per capita expenditure for the treated and Y_0 is the value for the untreated.

ATE = E(Δ)=E[Y_1/ $X, D = 1$] – E[Y_0/ $X, D = 0$] .4

ATET = E(Δ/D=1)=E[Y_1/ $X, D = 1$] – E[Y_0/ $X, D = 1$] .5

The propensity score matching can use different models to estimate the propensity score. This study used the logit model for drought adaptation strategies by including independent variables X which are gender household size, married, divorced, widow, cohabitation, farm experience pension, grant, on-farm-income, off-farm-income, loan, years of education, age, form employment and self-employment. Although PSM seeks to compare the differences between adopters and non-adopters with identical underlying traits, it cannot correct unobservable bias (Asfaw et al., 2012). PSM can control only observed variables.

Limitations of the study

The data were collected shortly after the COVID-19 lockdown had been lifted. This posed a challenge as some households were not willing to participate when conducting the questionnaire in fear of possibly contracting COVID-19. Although all COVID-19 preventive measures were adhered to and social distancing was practiced, the respondents were still skeptical. Some households did not even allow the enumerator to enter their yards.

Ethical consideration

The research was approved by the North-West University Ethical Clearance Committee. Since primary data were collected through administration of questionnaires, all the participants were well informed with regard to the purpose of the study and how the results of the study would be used. The questionnaires clearly stated who the researcher was, where the researcher was from and the purpose of the study. Participation was voluntarily and only adult members of the households were eligible to be interviewed, their responses would be kept confidential, and they could withdraw from participating at any time during interviews.

RESULTS AND DISCUSSION

Households' Socioeconomic and Demographic Characteristics

The results presented in Table 1 show that 19% of the respondents were between 40 and 49 years old. About 24% of the respondents were between 50 and 59 years old. Majority of the household heads (35%) were old being 60 years and above. This suggests that most of the households' heads were adults. The probable reason why there were more individuals who were older than 40 years can be attributed to the fact that younger people usually migrate from rural areas to urban areas in the hope of getting better work (Mutekwa, 2016). The Table further shows that 63% of the respondents were male. Males are typically recognized as the head of the households in most rural and traditional settings, and they are the primary decision makers (Cheteni *et al*., 2019). In addition, based on their marital status, 37% was married, 31% was single, 21% were widowed, 8% were cohabiting and 3% were divorced. According to Moore and Govender (2013), people living in urban regions had a 1.3 times lower likelihood of getting married than people living in rural areas.

Table 1. Socio-economic and demographic characteristics of rural households

Characteristics	Frequency	Percentage
Age		
20 – 29	21	6
30 – 39	59	16
40 – 49	69	19
50 – 59	85	24
60 and above	126	35
Gender		
Male	226	63
Female	134	37
Household Size		
1 – 2	67	19
3 – 4	95	26
5 – 6	182	51
7 – 8	16	4
Farming Experience		
< 5	238	66
6 – 10	55	15
11 – 15	27	8
16 - 20	16	4
> 20	24	7
Marital Status		
Single	110	31
Married	134	37
Divorced	12	3
Widow/Widower	75	21
Cohabiting	29	8
Education Status		
No Education	5	1
ABET (Level 1 – 4)	17	5
Primary (Grade 0 – Grade 7)	63	18
Secondary (Grade 8 to Grade 12)	151	42
Tertiary (TVET College/University)	124	34

Source: Author's conception (2021)

The results further showed that 51% of the households had households' sizes between 5 – 6. This is quite a large household size, and it can be difficult, especially in years of drought when spending more on family needs will be necessary. The findings indicated that majority of the households' heads (43%) went to school for 12 years. This means that they went to school all the way up to matric (Grade 12). About 34% had about 15 years of schooling experience. This meant that these individuals got an opportunity to obtain a tertiary qualification. Roughly 17% only ended their schooling years at primary level with only 7 years of schooling experience. About 5% of the household heads had about 4 years of schooling experience which means that they only got an opportunity to go to school up until primary school, however, got an opportunity to also do ABET. Lastly, 1% of the household heads had no schooling experience altogether. According to these findings, majority of the households' heads were literate, which meant they were most likely to be knowledgeable on drought as it affects livelihoods in the study area.

According to the results of the study, 66% of the sampled households had 5 years or less of farming experience. About 34% of the households have farming experience above 5 years. For households to be able to cope with adverse effects of drought, they need to have some sort of farming experiences. A study by Zhou and Li (2022) confirmed this notion as it showed that having farm experience improves personality qualities of individuals, builds a certain amount of potential human capital which in turn results in helping households with self-adaptability, dealing with setbacks, and may have positive effects on the long-term development of households

Determinants of Per Capita Expenditures

The effects of drought adaptation techniques on rural households' welfare (consumption) in the JTGD were examined using the two-stage regression model. The mean VIF was 1.84, showing no evidence of multicollinearity among the variables. The Wald Chi Square statistic showed statistical significance ($p<0.01$). This implies that the estimated parameters in the regression model cannot be said to be jointly equal to zero. Also, the suspicion on income being endogenous was confirmed by conducting the Durbin and Wu-Hausman tests. The results are both statistically significant ($p<0.01$) and imply that income was indeed endogenous. To ensure that the selected instruments are valid, the Sargan (1958) and Basmann (1960) tests were carried out. The results both showed statistical insignificance ($p>0.05$). These results confirmed that the selected instruments are not weak.

The results in Table 2 further showed that income is with positive parameter (0.2046721) and statistically significant ($p <0.01$). This implies that income had influence on per capita consumption expenditure. Access to income means that households can afford nutritious food, pay for education, and pay for health care services (Hone and Marisennayya, 2019). Generally, an increase in income, increases per capita consumption expenditure (Pao and Tsai, 2011). Rural households tend to spend most of their income on food items. However, once they have increased income, they can now afford to adjust their spending to non-food items, and save some money. The parameter of household pension is positive (2101.87) and statistically significant ($p<0.01$). This shows that pensioners had their average per capita expenditure being higher by R2101.87, when compared with non-pensioners. This result is in line with the study by Zhao *et al*. (2016) who asserted that pension income promoted consumption expenditures. Zheng and Zhong (2016). further stated that participation in pension programme promoted consumption expenditures. Studies with similar findings are Kang *et al*. (2022) and Chen *et al*. (2015).

The parameter of household size is negative (-625.63) and statistically significant ($p<0.01$). This finding shows that an increase in the number of household members by one person will lead to a decrease in per capita consumption expenditures by R625.63. This finding is expected and relays the financial burdens that often face households with large sizes. The finding is related to that of Heshmati *et al*. (2019) but contrary to those of Hone and Marisennayya (2019) and Kiran and Dhawan (2015). In another study, Rahim *et al*. (2018) reported that household size did not show statistical significance.

The parameter of grant recipient is negative (-1928.29) and statistically significant ($p<0.01$). This implies that households who were receiving grants had their per capita expenditure lower by an average of R1928.29. This is expected because social grant recipients are often among the poorest in the society. Also, the amount of grant received is often insufficient for the primary recipient's monthly needs, talk less of the whole household (Le Roux, 2002).

Finally, among the included drought adaptation strategies, only the parameter of crop diversification shows statistical significance ($p<0.05$) with positive sign. This implies that households who were diversifying crop production had their average per capita expenditure higher by R517.56. The role of crop diversification in promoting farm resilience and incomes cannot be overemphasized (Kurdyś-Kujawska *et al*., 2021). This is particularly relevant for farmers facing some environmental challenges like drought. The finding is in consonance with those of Pellegrini and Tasciotti (2014), Mango et al. (2020), and Basantaray and Nancharaiah (2017).

Table 2. The Results of 2SLS Regression

Percap	**Coef.**	**Std. Err.**	**z-stat**
Demographic variables			
Income	.2046721	.0247801	8.26
Gender	-123.2227	182.8829	-0.67
Household size	-625.6278	52.72002	-11.87
Married	-170.8089	215.3876	-0.79
Divorced	-329.2826	444.9907	-0.74
Widow	-211.408	240.4844	-0.88
Cohabitation	-221.586	297.7723	-0.74
Farm type	-10.91157	147.2182	-0.07
Farming experience	-2.13513	13.43292	-0.16
Pension	2101.868	701.8721	2.99
Grant recipient	-1928.291	701.5129	-2.75
Access to loan	196.0937	178.0242	1.10
Savings	-106.936	114.1062	-0.94
Adaptation variables			
Crop diversification	517.5555	258.4695	2.00
Livestock diversification	104.1021	201.6551	0.52
Rainwater harvesting	58.80798	290.7281	0.20
Drought tolerant crop	235.3521	462.1245	0.51
Crop rotation	-100.3543	423.5707	-0.24
Constant	3457.372	313.3077	11.04
Number of observations	360		
Wald chi2(18)	412.49***		
R-squared =	0.5979		
Tests of endogeneity			
Durbin (score) chi2(1)	10.9655***		
Wu-Hausman F (1,340)	10.6817***		
Tests of overidentifying restrictions			
Sargan (score) chi2(3)	5.72161		
Basmann chi2(3)	5.4587		

ATE and ATET Across Adopted Drought Adaptation Strategies

Table 3. ATE and ATET Across the Drought Adaptation Methods

Adaptation Methods	ATE		ATET	
	Coeff	z- stat	Coeff	z- stat
Crop Diversification	497.1556	2.23	148.3243	0.40
Livestock Diversification	-38.225	-0.20	294.6	1.21
Rainwater Harvesting	-263.5139	-1.34	-142.3571	-0.24
Drought Tolerant Crop	479.6083	0.21	-1450.1	-1.12
Crop Rotation	-50.29722	-0.14	166.6667	0.66

Table 3 presents the PSM estimates of the impacts of adaptation methods on welfare (per capita consumption expenditure). The results showed that households who adopted crop diversification had significantly higher average per capita expenditure. Specifically, users of crop diversification had their per capita consumption expenditure being higher by R497.16 when compared with non-adopters. It should be noted that this is the only parameter that is statistically significant in Table 3. The result further buttresses the role of crop diversification in drought prone areas of Northern Cape province. In addition, the ATET of crop diversification is statistically insignificant ($p>0.05$) but with positive sign. This implies that for the adopters of crop diversification, although their per capita expenditure after adopting is higher than what obtains if they had not adopted, the difference (R148.32) is not significantly different.

CONCLUSION

Drought is a notorious environmental hazard affecting the livelihoods of poor and vulnerable households in the Northern Cape province of South Africa. Although its impacts cut across different sectors of the provincial economy, rural areas are often more affected due to their dependence on farming. Therefore, research efforts for a clearer understanding of the impact of drought adaptation strategies on households' welfare will provide some development policy stances that are empirically motivated. This study has demonstrated that drought adaptation strategies had very little impacts on per capita expenditure. This underscores the severity of the impacts of drought on agricultural productivity in some years, thereby making adaptation either completely ineffective or with just very little impacts. The results highlight the role of crop diversification in promoting per capita expenditure, while households' incomes is fundamentally important. The findings have also shown the need for additional assistances for drought affected households because current welfare grants are unable to enhance their per capita expenditure. In addition, initiatives to control women fertility will promote households' welfare because our findings revealed negative association between household size and per capita expenditure.

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CONFLICT OF RESEARCH INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

PA designed the study, analysed the data and wrote the report for her MSc degree. TC and AS reanalyzed some of the data, drafted the article and provided professional comments.

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