The association of depression, impulsivity and suicidal ideation with organophosphate pesticide exposure amongst South African farm workers

by

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Plagiarism declaration

Dissertation Title: *The association of depression, impulsivity and suicidal ideation with organophosphate pesticide exposure amongst South African farm workers*

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Dedication

This thesis is dedicated in loving memory of my late father, AG Kootbodien, who was and always will be my inspiration.

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Definitions

Chronic low dose organophosphate pesticide exposure

Chronic low dose organophosphate pesticide exposure is defined in this study as cumulative occupational exposure to organophosphate pesticides over a prolonged period of time in the absence of acute poisoning.

Endogenous construct

An endogenous construct is a latent variable that is dependent and determined by factors in the model (Hair, 2010). Examples in this study include *organophosphate exposure*, *depression*, *impulsivity* and *suicide*.

Exogenous variables

An exogenous construct is a latent variable that is independent and determined by factors outside the model (Hair, 2010). Examples in this study include *age* and *gender*.

Heywood case

A Heywood case is a negative error variance found under certain circumstances in factor analysis when the sample size is too small or too many factors extracted.

A history of past organophosphate pesticide poisoning

A history of past OP poisoning was classified as a categorical variable from the following question "Have you ever been sick from pesticides?" as (0= no history of past OP pesticide poisoning, 1= history of past OP pesticide poisoning).

An identified construct

A construct is considered identified within a SEM analysis when three or more items represent a factor.

An illogical path estimate

A standardised path estimate ranges between zero and one. An illogical standardised path estimate is when the estimate is more than one or less than zero.

Latent construct

A latent construct or variable is a hypothesised and unobserved concept that can be represented by observable or measured variables (Hair *et al*, 2010; Kelloway, 1998).

Measurement model

Within the structural equation model, the measurement model represents how measured variables come together to represent the theory.

Organophosphate compounds

Organophosphate compounds are derived from esters of phosphorous compounds, commercialised for agricultural, domestic and garden use of insecticides that have the potential to cause negative health effects (Kwong, 2002).

Structural equation modelling

Structural equation modelling is a multivariate statistical analysis technique for testing and estimating causal relationships that is a combination of factor analysis and multiple regression analysis (Hair *et al*, 2010).

Structural model

Within the structural equation model, the structural model represents the theory that shows how the constructs are related to other constructs.

An under-identified construct

An under-identified construct within a SEM analysis is defined as having one or two items to represent a factor.

Abbreviations

BIS-11	Barratt's Impulsivity Scale
BSI	Brief Symptom Inventory
CFA	Confirmatory factor analysis
CFI	Comparative fit index
Cronbach's α	Cronbach's alpha coefficient
DALY	Disability adjusted life years
GHQ-28	General Health Questionnaire
GOF	Goodness-of-fit
JEM	Job exposure matrix
LISREL	LInear Structural RELations
NNFI	Non-normed fit index
OP	Organophosphate
PNFI	Parsimony normed fit index
RMSEA	Root mean square error of approximation
SEM	Structural equation modelling
SSI	Beck's Scale of Suicidal Ideation
KMO	Kaiser-Meyer-Olkin test of sampling adequacy

Summary

Background

Organophosphate pesticides are commonly used and generally highly toxic. Acute OP pesticide exposure has been linked to negative psychological and behavioural effects. Consensus has yet to be reached on the negative psychological effects resulting from long term low dose OP pesticide exposure. This study sought to determine the association of chronic low dose OP pesticide exposure with depression, impulsive behaviour and suicidal ideation in farm workers in the Western Cape, updating a previous analysis using a structural equation modelling (SEM) approach.

Objectives

The objectives were to evaluate the validity and reliability of four neurobehavioral instruments used in the study and to test three models hypothesised as possible causal pathways between OP exposure and depression, impulsive behaviour and suicidal ideation (summarised below).

- Model 1: Adult farm workers exposed to long term low dose OP pesticides have an increased risk of depression which in turn translates to an increased risk of suicidal ideation when compared to unexposed farm workers.
- Model 2: Adult farm workers exposed to long term low dose OP pesticides have an increased risk of impulsive behaviour which in turn translates to an increased risk of suicidal ideation when compared to unexposed farm workers.
- Model 3: Adult farm workers exposed to long term low dose OP pesticides have an increased risk of both depression and impulsive behaviour. In addition, there may be an interaction between depression and impulsive behaviour which may modify the risk for suicidal ideation in adult farm workers exposed to low dose OP pesticides when compared to unexposed farm workers.

Methods

A secondary analysis was performed on data from a cross-sectional study conducted in 2002 on 57 farms in the rural Western Cape Province of South Africa. Of the 817 main study participants, sampled using single-stage clustering by farm, missing data prompted the removal of 65 participants by list-wise deletion, leaving 752 participants for the purposes of SEM. Participants were screened for psychological symptoms using the General Health Questionnaire (GHQ-28), Brief Symptom Inventory (BSI), Barratt's Scale of Impulsivity (BIS-11) and Beck's Scale for Suicidal Ideation (SSI). The validity of the four instruments was assessed by determining Cronbach's alpha coefficients. Preliminary analyses using a single construct (total score) of the SSI resulted in poorly fitted SEM models. Therefore factor analysis using principal component factor extraction, followed by a varimax rotation, was applied to identify the underlying factor structure of the SSI questionnaire in order to enhance SEM model fit. Three a priori hypothesised models were tested using SEM to identify potential causal relationships between chronic low dose OP pesticide exposure with depression, impulsive behaviour and suicidal ideation.

Results

Of the 752 participants, 59.4% (447) were male. The proportion of the study population categorised as having psychological distress were based on two instruments: 18.6% (140) of participants on the GHQ-28 (cut-off score ≥ 24) and 22.5% (169) of participants based on the standard t-scores of the global severity index (T_{GSI}) of the BSI (cut-off score ≥ T_{63}). Median cut-offs were used to categorise 50.7% (381) of the participants as having impulsive behaviour based on the BIS-11 (median cut-off score ≥ 54) and 50.5% (380) as having suicidal ideation based on the SSI (median cut-off score ≥ 1).

Factor analysis of the SSI in the male sub-sample revealed three factors with significant and non-trivial standardised factor loadings but low reliability. The original factors reported by Steer *et al* (1993) had an internal reliability of 0.75 that was considered to be "adequate" i.e. Cronbach's alpha (α) ≥ 0.7. The internal reliability of the GHQ-28 (4-items, Cronbach's α =0.72), BIS-11 (3-items, Cronbach's α = 0.69) and CAGE questionnaire (4-items, Cronbach's α = 0.76) were also considered to be "adequate". The BSI (9-items, Cronbach's α = 0.91) had a "good" internal reliability i.e. Cronbach's α ≥ 0.80.

Structural equation modelling examined three hypotheses in the development of depression, impulsive behaviour and suicidal ideation. Twelve individual measurement models and structural models were assessed separately as valid i.e. low χ^2 with an insignificant *p*-value, χ^2/df less than 3, RMSEA less than 0.08, CFI and NNFI greater than 0.90. Two models were presented for each hypothesis where, respectively, OP exposure was measured by, firstly, cumulative years exposed in the agriculture sector and, secondly, time exposed performing any of eight farming / spraying activities, combined into one measure.

In model 1, there was no association between long term low dose OP exposure and depressive symptoms in male farm workers when OP exposure was measured by cumulative years exposed. When OP exposure was measured by the time exposed performing any of the eight farming / spraying activities combined into one measure, there was a negative association between OP exposure and depressive symptoms in male farm workers. Additional risk factors, a positive CAGE score and a past history of OP poisoning, were positively associated with depressive symptoms. Depressive symptoms were positively associated with suicidal ideation.

For model 2, there was no association between long term low dose OP exposure and impulsive behaviour in male farm workers in both variations of the OP exposure variables. A risk factor associated with impulsive behaviour was low socioeconomic score. Impulsive behaviour was positively associated with suicidal ideation.

For model 3, there was no association between OP exposure and <u>both</u> depressive symptoms and impulsive behaviour in male farm workers in the two variations of OP exposure. However, risk factors for depressive symptoms were age (being older increased risk) and a history of past OP poisoning. A risk factor associated with impulsive behaviour was low socioeconomic score. There was no significant interaction between depressive symptoms and impulsive behaviour. Impulsive behaviour and depressive symptoms were positively associated with suicidal ideation.

Discussion

The negative association found between chronic low dose OP exposure and depressive symptoms may be explained by a variation of the healthy worker effect where farm workers with mental illness would be less likely to be assigned to pesticide applicator duties. Exposure misclassification may have contributed towards the lack of an association between OP exposure and the mental health outcomes. The generalisability of the results was affected by intrusion of convenience sampling and the restriction to the male subsample for the SEM analysis.

Conclusions

This thesis represents the first validation of the SSI questionnaire in a South African population. There was no evidence in this study for the association of low dose long term OP exposure with depression, impulsivity and suicidal ideation. The study highlights the prevalence of psychological distress among farm workers that may be potentially attributable to following risk factors: a history of past OP poisoning, age (being older increased risk), a positive CAGE score and lower socioeconomic score. These findings emphasises the need for improved surveillance and earlier recognition of mental health conditions prevalent amongst similar agricultural populations. Longitudinal and prospective studies are recommended for future research.

CHAPTER ONE

1. Introduction

1.1 Background

1.1.1 Pesticides

OP compounds are used as pesticides in agricultural settings throughout the world. These compounds are usually esters of phosphoric acid and phosphothioic acid (Kwong, 2002). First synthesised in 1854, OP compounds were only investigated as a potential pesticide in the early 1920s in Germany. In 1936, Dr Gerhard Schrader, a German industrial chemist, accidentally synthesised the first nerve agent while conducting pesticide research, resulting in the subsequent production of chemical warfare agents i.e. sarin, tabun, soman, etc. OP compounds were reintroduced worldwide for pesticides use after World War II.

Highly hazardous pesticides were defined by the FAO/WHO Joint Meeting on Pesticide Management in 2008, as having one or more of the following characteristics: acute toxicity, carcinogenicity, mutagenicity, reproductive toxicity, listing under the Stockholm Convention on Persistent Organic Pollutants (POPS), or evidence of severe or irreversible adverse effects on human health (FAO/WHO, 2008; WHO, 2009). Based mainly on the acute toxicity of the active ingredient, OP pesticides are classified as moderately to highly hazardous pesticides (WHO, 2009).

Pesticide usage is regarded as a cost effective method of controlling pests in agriculture, especially in developing countries, where low labour input is required and large areas can be treated quickly and efficiently. Potential benefits to farmers include an increase in agricultural productivity, and protection of crops and plantations resulting in increased economic benefit (Ecobichon, 2000). However the disadvantages to the use of pesticides in agriculture include the persistence of pesticides residues in food and possible ground water contamination (Kookana and Simpson, 2000). An additional harmful effect includes the effects of exposure during application and handling of pesticides on workers as well as on farm worker communities through, for example, the drift of sprays.

1.1.2 Farming and pesticide exposure

Farm workers are exposed to pesticides as a result of their occupation. Farm workers who handle OP pesticides directly are regarded as being at higher risk of exposure than workers who do not handle pesticides directly e.g. pesticide mixers and applicators versus general farm workers (Jaga and Dharmani, 2003). Global pesticide production has been increasing over the last forty years, from about one million ton per year in 1960 to 3.75 million tons per year in 2000 (WHO, 1990; Tilman *et al,* 2001). Further, Tilman *et al* (2001) forecasted that if past agricultural patterns continue, annual global pesticide production would be 6.55 million tons by 2020 and 10.1 million tons by 2050. A decade ago, South Africa had the largest market for pesticide use in Sub-Saharan Africa (Dinham, 1993). A study analysing the South African pesticide market sales data showed a significant increase in the agricultural use of pesticides in 1999 compared to 1994 (Dalvie *et al*, 2009). Therefore with the increase in pesticide usage and exposure, farm workers may have an elevated risk of occupational pesticide poisoning.

Occupational exposures to OP pesticides are mainly via dermal absorption, inhalation and oral ingestion. The effects of OP pesticides on human physiology are multiple and complex. One mechanism of action is through the inhibition of the acetylcholinesterase (AChE) enzyme, leading to an accumulation of acetylcholine at cholinergic synapses (Eddleston and Bateman, 2007). The excess acetylcholine cause constant acetylcholine receptor triggering, resulting in malfunction of the autonomic, somatic and central nervous systems (Aardema *et al*, 2008). However in the nervous system, most of the actions appear to be related to phosphorylation of protein targets, acetylcholinesterase and neuropathy target esterase or direct binding of OP to nicotinic receptors (Milestone *et al,* 1998). The speed of onset, severity and duration of toxicity caused by different OPs are variable and may depend on a multitude of factors (Eddleston and Bateman, 2007).

OP pesticide poisoning can present in the following ways: an acute cholinergic crisis, intermediate syndrome (IMS) and delayed neuropathy (Ray and Richards, 2001; Yang and Deng, 2007). In addition, exposure to some OP's may have chronic long-term effects: cancer, genotoxicity and neurotoxicity including psychological effects (Sanborn *et al*, 2004).

1.1.3 Pesticide poisoning

Pesticide poisoning, either unintentional or self-inflicted, is a serious public health problem in many parts of the world. Over twenty years ago, the World Health Organisation approximated one million unintentional and two million intentional cases of acute pesticide poisoning each year, resulting in about 220 000 deaths (WHO, 1990). Data extrapolated from a study in Sri Lanka suggested that 2.9 million cases of acute pesticide poisoning required hospital admission with 220 000 deaths occurring annually in developing countries (Jeyaratnam, 1985a). Subsequently, pesticide ingestion was found to be a leading method of suicide, accounting for a third of people who die by suicide every year (Gunnell *et al*, 2007).

The world report on violence and health found an association between mental disorders and fatal self-harm (Krug *et al*, 2002). In addition, the role of impulsive self-poisoning in the absence of mental disorders has also been suggested (Eddleston and Phillips, 2004). Increasingly, the role of access to hazardous pesticides have been investigated in Asian populations where a substantial proportion of people who die of self harm do not have a diagnosable mental illness (Bertolote *et al*, 2006; Phillips *et al*, 2002; Zhang, 2009).

Pesticide poisoning is a notifiable medical condition in South Africa (Health Act No 63, 1977), however the monitoring and surveillance system of pesticide poisonings has been found to be sub-optimal (London and Baillie, 2001). London *et al* (1994) approximated 35-40% of pesticide poisoning notification in South Africa was due to suicide. However, underreporting of non-suicide pesticide poisoning e.g. occupational pesticide poisoning may have overestimated suicide as a proportional cause (London *et al*, 1994). Over the last decade, 12 364 cases of pesticide poisoning were reported in South Africa between 2000 and 2008 (DOH, 2008) with the Western Cape Province accounting for 4% of the burden.

1.2 Background to the project

This study was a collaborative project between University of Cape Town and Peninsula Technikon in South Africa with Utrecht University in the Netherlands conducted in 2002 The study was funded initially by the South Africa-Netherlands Research Programme on Alternatives in Development (SANPAD), a collaborative research programme that has been financed by the Netherlands Ministry of Foreign Affairs since 1997. Funding has subsequently expanded to include 2 National Research Foundation (NRF) grants with US collaboration.

1.3 Justification

It is known that OP pesticides are used as a means to commit suicide. It has also been established that acute poisoning with OP pesticides results in psychological harm. However, the evidence for chronic low dose OP pesticide exposure leading to affective changes associated with suicide is not clear (Colosio *et al*, 2003; Kamel and Hoppin, 2004; London *et al*, 2005).

This study aims to bridge the gap in the evidence presented in the literature review by contributing scientific knowledge in the area of psychological effects of low dose chronic OP pesticide exposure in South African farm workers, where limited studies have been published previously.

OP pesticide exposure can be prevented by informed and careful explanation of the safe handling practices of pesticides. Thus, if one can show an association between OP exposure and psychological effects, the findings may be used to lobby for interventions to decrease exposure and potentially limit detrimental mental health effects.

In the primary study, Major (2010) aimed to determine the relationship between chronic OP exposure and psychological effects (particularly depression and its predisposition to suicide) in the study population using logistic regression analysis. The purpose of the secondary analysis serves to further explore the relationship between chronic exposure to low dose OP pesticides and depressive symptoms, impulsive behaviour and suicidal ideation of the study population using SEM. The use of this methodology hoped to provide a more rigorous and nuanced analysis of the exposure-outcome relationships than that achieved by Major (2010) in the study population. In addition, the study aims to identify risk factors associated with the development of suicide in agricultural populations. The identification of these relationships would assist in detecting farm workers who may be at higher risk of suicide.

1.4 Objectives

The study objectives were:

1. To determine the validity and reliability of tools used to assess depressive symptoms, impulsive behaviour and suicidal ideation in a farm worker population in the Western Cape Province, South Africa.

2. To explore the relationship of long term low dose OP pesticide exposure with depressive symptoms, impulsive behaviour and suicidal ideation. Three models were considered as possible causal pathways, in which exposure to low dose OP pesticides are implicated for development of depressive symptoms and suicidal ideation as an outcome based on a review by London *et al* (2005).

   The hypotheses below are depicted visually in Figure 1.1.

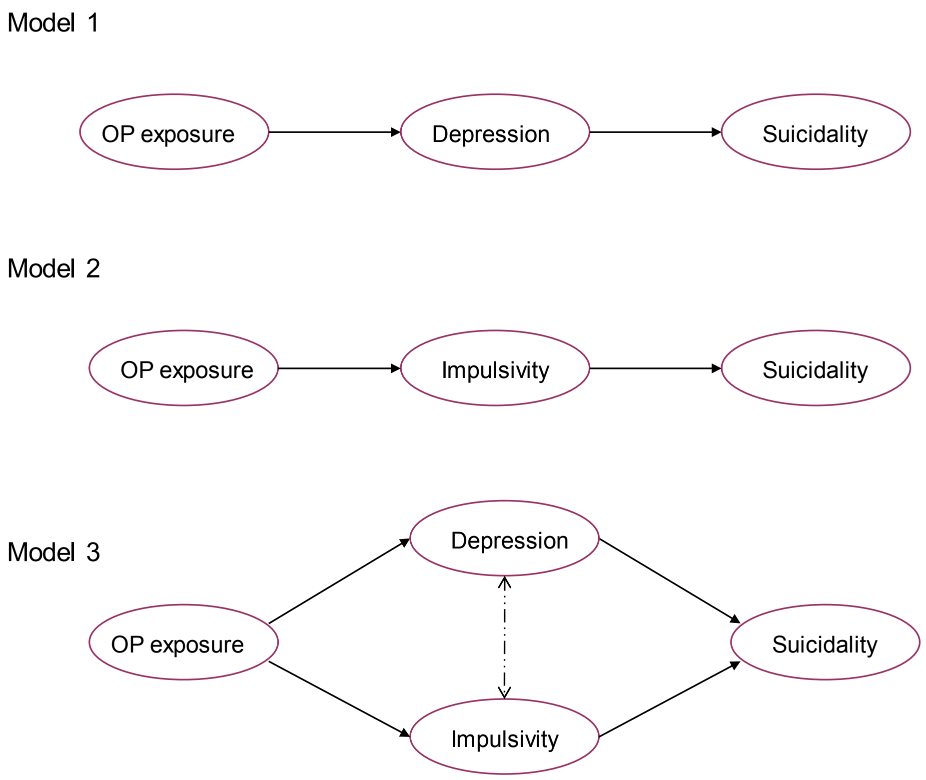

Figure 1.1 Diagrammatic models depicting study hypotheses

i. Model 1

Hypothesis 1: Adult farm workers exposed to low dose OP pesticides have an increased risk of depression which in turn translates to an increased risk of suicidal ideation when compared to unexposed farm workers.

ii. Model 2

Hypothesis 2: Adult farm workers exposed to low dose OP pesticides have an increased level of impulsive behaviour, which in turn translates to an increased risk of suicidal ideation when compared to unexposed farm workers.

iii. Model 3

Hypothesis 3 (a): Adult farm workers exposed to low dose OP pesticides have BOTH an increased risk of depression and an increased level of impulsive behaviour compared to unexposed farm workers.

Hypothesis 3 (b): Given *3(a),* there may be an interaction between depression and impulsive behaviour which may modify the risk for suicidal ideation in adult farm workers exposed to low dose OP pesticides when compared to unexposed farm workers.

1.5 Delineations

This study was limited to adult farm workers engaged in occupational OP pesticide applicator activities in the Western Cape, South Africa. This thesis did not include exposure to OP pesticide during domestic application for garden or household purposes or exposure from environmental drift. The farms included in the study were limited to grape farms and did not include other kinds of agricultural production such as livestock farms or horticulture other than vineyards.

1.6 Thesis Overview

This thesis is organised into five chapters. Chapter one introduced the problem of pesticide exposure among farm workers and presented the rationale for the study including the aims and objectives. Chapter two presents the review of literature exploring associations found between psychological health outcomes and occupational exposure to OP pesticide. Chapter three describes the study methods. Chapter four summarises the findings of the analysis in three parts: the exploratory data analysis, bivariate analysis and multivariate data analysis. Chapter five concludes the thesis where the key study findings and public health implications are discussed and recommendations are outlined. Study limitations are highlighted and future research is suggested.

CHAPTER TWO

2. Literature review

This chapter examines the current literature on the role of occupational OP pesticide exposure in the development of potential psychological effects, specifically depression, impulsivity and suicide. The prevalence of these conditions is presented, associated risk factors are discussed and the difficulties with exposure assessments are explored.

2.1 Introduction

In the developing world, OP pesticides have been become increasingly used in the agricultural sector as they are less persistent and less able to bio-accumulate in the environment compared to organochlorine compounds. OP pesticide exposure can produce acute toxicity resulting in high morbidity and mortality (Jaga and Dhaarmani, 2003). Though the psychological effects of acute toxicity have been well documented, the psychological effects, specifically depression and suicide, of low dose long term occupational OP pesticides continue to be debated. Colosio *et al* (2003) reviewed the epidemiological literature that explored the potential neurobehavioral toxicity of pesticides, including OP pesticides, DDT and fumigants. While methodological shortcomings of the studies were highlighted, most studies generally yielded contradictory or equivocal results. In a review by Kamel and Hoppin (2004), the authors found that most studies showed effects on cognitive and psychomotor neurobehavioral function in chronically exposed individuals without a history of poisoning, although clinical measures of peripheral nerve function like vibration sensitivity and nerve conduction were generally not affected.

2.2 OP pesticide exposure and psychological outcomes

Mental disorders are a major contributor to the burden of disease across the world, accounting for 14% of global burden attributable to neuropsychiatric disorders (Prince *et al*, 2001). In Sub-Saharan Africa, neuropsychiatric disorders account for nearly 10% of the total burden of disease (Lopez *et al*, 2006).

Studies have shown that farmers are subjected to a large number of occupational stressors, many of which have been aggravated in recent years by changes in farming practice and economic factors, contributing to an increased level of stress (Gregoire, 2002; Fraser *et al*, 2005), depression and anxiety (Eisner *et al*, 1998) and increased rates of suicide (Booth *et al*, 2000). Over twenty years ago, labour conditions on South African farms were found to be among the poorest of all the employment sectors (Davies, 1990). In addition, farm workers were at increased risk of mental illness by the ongoing implementation of the "DOP' system where farm workers were provided with alcohol as part of their farm work (Scully, 1992; London, 2000).

Low dose toxicity effects of OP pesticides were described by Davies *et al* (2000) to include mood instability, suicidal thinking and behaviour and cognitive impairment. Ahmed and Davies (1997) also described chronic OP pesticide-induced neuropsychiatric disorder (COPIND), which may be induced by chronic low level exposure to OP but does not include cholinergic symptoms. In COPIND the common clinical symptoms may include impairment in memory, concentration and learning; anxiety, depression and psychotic symptoms, chronic fatigue, peripheral neuropathy, autonomic dysfunction and extra-pyramidal symptoms such as dystonia, resting tremor, bradykinesia, postural instability and rigidity of facial muscles and non-responsiveness to levo-dopa treatment (Salvi *et al*, 2003).

As noted in section 1.3, there is a dispute whether low dose long term occupational OP exposure is associated with psychological effects, specifically depression and suicide. Though this association has been demonstrated in several studies (Bazlewicz-Walczak *et al*, 1999; Salvi *et al*, 2003; Steenland *et al*, 2000; Stephens *et al*, 1995; Zhang *et al*, 2009); other studies have found no association (Levin *et al*, 1979; MacFarlane *et al*, 2011; Picket *et al* 1998). The literature is therefore equivocal on whether long term low dose OP exposure is a causal factor in the development of psychological effects (Colosio *et al*, 2003; London *et al*, 2005). In addition, limited epidemiological studies have been undertaken examining the role of OP pesticides and impulsivity in the development of suicide. The literature presented below aims to assess the role of occupational OP exposure in the development of depression, impulsivity and its predisposition to suicide.

2.2.1 Suicide

2.2.1.1 Global perspective on suicide

The World Health Organisation (2003) estimated that suicide was an important cause of premature mortality accounting for 849 000 deaths worldwide. Global suicide rates from 1950 to 1995 showed a relative constant male predominance with ratios of male to female suicide rates of 3.2:1 in 1950 and 3.6:1 in 1995 (Bertolote & Fleischmann, 2002). China appeared to be the exception, where suicide rates in females were consistently higher than the than suicide rates in males, particularly in rural areas (Phillips & Zhang, 2002). In all countries suicide is one of the three leading causes of death among people aged 15-34 years; and until recently suicide was predominantly among the elderly, but now suicide predominates in younger people in both absolute and relative terms, in a third of all countries (WHO, 1990; Bertolote & Fleischmann, 2002).

2.2.1.2 International impact of pesticides on suicide

Over twenty years ago, the World Health Organisation estimated approximately one million unintentional and two million intentional cases of acute pesticide poisoning occur each year, resulting in about 220 000 deaths (WHO, 1990). A review by Eddleston (2000) revealed that pesticides are the commonest means of self-poisoning in many rural areas of Asia and is associated with high mortality rate. Subsequently, pesticide ingestion was found to be a leading method of suicide, accounting for a third of people who die by suicide every year (Gunnel *et al*, 2007).

2.2.1.3 Current suicide trends in South Africa

Suicide accounts for 10% of all injury deaths in South Africa (Donson, 2007). This extrapolates to between 5514 and 7582 deaths per year, and between 110 280 and 151 646 suicide attempts per year (Burroughs and Schlubusch, 2008). The South African Stress and Health Survey (SASH) was the first prevalence study of mental disorders derived from a nationally representative sample of South African adults, in collaboration with the World Mental Health Survey Initiative (WHMSI). The study showed 9.1% of the adult respondents reported lifetime suicidal ideation, 3.8% a suicide plan and 2.9% a suicidal attempt (Joe *et al*, 2008).

In South Africa, approximately 40% of pesticide poisonings reported to the Department of Health over the period of 1987 to 1991 were due to suicide (London *et al*, 1994). However severe underreporting of non-suicide pesticide poisoning suggests that the true percentage may be lower.

Suicide is cited predominantly as the reason for pesticide poisoning in Africa. Two Zimbabwean studies evaluated the trends in pesticide poisoning requiring hospital admission. Dong and Simon (2001) assessed 599 cases of acute OP poisoning from 1995 to 2000, of which74% referred to suicide as the main reason for pesticide poisoning. Tagwireyi *et al* (2006) found 42.2% of 914 acute pesticide poisoning cases evaluated over a period of two years (January 1998 to December 1999), were as a result of anticholinesterase-type pesticides, accounting for 70.9% of all fatalities. The case fatality rate of deliberate self-poisoning was significantly higher than accidental self poisoning (6.5 deaths / 100 admissions versus 0.8 deaths / 100 admissions.

2.2.1.4 Epidemiological studies on OP pesticide exposure and suicide

The focus of following studies presented below explores a possible causal relationship between OP pesticide exposure and suicidal ideation, shifting from studies presented previously of pesticides as an agent of suicide. Four ecological studies have appraised the potential of OP pesticide exposure to contribute to the development of suicide. In 1991, Crombie reviewed deaths from suicide, accidental poisoning and undetermined causes from 56 local government districts during 1974-1986 in Scotland. The author reported a correlation between OP use and suicide rates in Scotland. Similarly, Kelly *et al* (1995) illustrated a disproportionately high suicide rate among veterinarians exposed to OP pesticides. Later, Parron *et al* (1996) reviewed 251 suicide cases over a 12-year period from 3 different areas of Almería province in Spain, to explore the relationship between high suicide rates in an intensive agricultural area and farmers with chronic exposure to pesticides at risk to develop mood disorders. The findings showed an increased suicide rate in the areas with a high prevalence of OP usage compared to non-OP areas among Spanish farm workers. More recently, Meyer *et al* (2010) compared the suicide mortality rates observed among agricultural workers from a pesticide-intensive area in Brazil to the suicide mortality frequency in three reference populations. Study results showed that agricultural farm workers were at higher risk of suicide than the reference population, and risk of death by suicide was significantly higher among agricultural workers who lived in areas of Rio de Janeiro State where there were higher rates of pesticide expenditure per agricultural worker.

Though these studies showed a correlation between OP exposure and suicide, findings based on ecological studies are often difficult to interpret because the relationship between exposure and disease at population level may not reflect the same relationship at individual level and may be subject to an ecological fallacy. For that reason, evidence from studies with designs less susceptible to bias was considered more scientifically valid.

Epidemiological studies present conflicting results between pesticide exposure and suicide. Pickett *et al* (1998) conducted a case-control study among 1457 Canadian male farm operators who committed suicide (between 1971 and 1987) and 11656 matched controls of farm operators who were alive at the time of death of individual cases. There appeared to be some evidence of an association between herbicide use and suicide among a sub-group of Canadian farmers (OR= 1.17; 95% CI: 1.08–2.71) for 1–48 vs. 0 acres sprayed. However, no substantial association was found between insecticides usage (number of acres sprayed) and suicide. No data was available on the type of insecticides used. In addition, the authors noted that misclassification of the exposure status between controls and cases may have contributed to a reduced association.

A cross sectional study of 9811 rural residents of Zheijing Province in China showed a positive association between the presence of pesticides in the home and suicidal ideation in the prior two years (unadjusted OR= 2.12; 95% CI:1.54–2.93) (Zhang *et al,* 2009). However, Macfarlane *et al* (2011) conducted a nested case-control study within a retrospective cohort of pesticide-exposed Australian workers from various industries. Of the 90 male suicide deaths and 270 male controls, pesticide exposure as measured by cholinesterase inhibition was not associated with a significant elevated risk of suicide (OR= 1.90; 95% CI: 0.73-4.93).

2.2.2 Depression

2.2.2.1 Global perspective on depression

Depression is characterised by depressed mood or loss of pleasure or interest in activities, lasting for at least two weeks as based on the DSM-IV classification (American Psychiatric Association, 1994). Depression is considered the most common psychiatric disorder in developing countries, accounting for 51.9 million DALYs or 3.4% of the global burden of disease (World Bank, 2006). Depression is ranked fourth among all causes of DALYs and is the leading nonfatal condition globally. Depression is more common among women than men (World Bank, 2006).

2.2.2.2 Depression in South Africa

The lifetime prevalence rate of a major depression episode was found to be 9.7% in the SASH study among adult respondents with the mean age of onset of 26 years of age (Tomlinson *et al*, 2009). Further, Tomlinson *et al* (2009) reported that males over the age of 50 years reported 128 days of role impairment i.e. days of work loss, using the Sheehan disability scale. Considering that the mean number of "role impaired" days reported for most chronic conditions were less than 15 (Kessler *et al*, 2001), this finding suggests that a major depressive episode is a serious impairing condition and has crucial implications for productivity in the workplace in South Africa.

2.2.2.3 Animal studies on OP exposure and depression

Several animal studies have addressed the potential of low-dose OP pesticides to produce toxicity, including behavioural effects. OP pesticides have been shown to cause acetylcholinesterase inhibition, resulting in an accumulation of acetylcholine at cholinergic synapses (Eddleston and Bateman, 2007). In addition, OP pesticides have been shown to disrupt the serotonergic system (Aldridge *et al*, 2003). The following studies explore the association between OP pesticides and animal models of depression that encompass deficiencies in the serotonergic system.

Aldridge *et al* (2005) exposed Sprague-Dawly rats postnatally to an OP pesticide, chlorpyrifos. When tested in adulthood, exposed animals showed abnormalities in behavioural tests that involve serotonergic mechanisms i.e. locomotor hyperactivity, increased open-arm time in elevated plus maze, anhedonia in the chocolate milk consumption test and cognitive impairment. Similarly, Chen *et al* (2011) repeatedly exposed 4-week-old adolescent male Sprague-Dawly rats to increasing increments of chlorpyrifos and then assessed serotonergic function by a battery of emotional behavioural tests. The authors found that repeated exposure to chlorpyrifos altered the performance of adolescent male rats in the animal models of depression and anxiety i.e. increased open-arm time in elevated plus maze, increased number of shocks in the Vogel's conflict test and decreased latency to feed in the novelty suppressed feeding test.

Lima *et al* (2011) evaluated depressive-like behaviour of Swiss mice subchronically exposed to an OP pesticide, methamidophos at adulthood. The depressive-like behaviour was determined by assessing the immobile behaviour of mice in the forced swimming and tail suspension test. The authors found during exposure to a lower dose of methamidophos, the mice exhibited increased immobility in the tail suspension test and inhibited brain acetylcholinesterase activity.

2.2.2.5 Epidemiological studies on OP exposure and depression

The role of OP pesticide exposure in the development of depression has not yet been established in epidemiological studies. An association between OP pesticide exposure and changes in mood and affect were found by Stephens *et al* (1995), Bazylewicz-Walczak *et al* (1999), Steenland *et al* (2000), Stallones and Beseler (2002) and in male pesticide applicators by Beseler et al (2008). However, no association was found between OP pesticide exposure and depressive symptoms in female spouses of pesticide applicators by Beseler *et al* (2006) and farm levels of anxiety in farm workers recently exposed to OP pesticides in an early study by Levin *et al* (1979).

Stephens *et al* (1995) measured psychiatric symptoms using the GHQ-28 questionnaire of 146 sheep farmers exposed to OP pesticides through sheep dipping activities with a control group of 143 quarry workers. Results showed that farmers were at higher risk of achieving a score above the "caseness" threshold of the General Health Questionnaire (OR=1.5, 95% CI 1.31-1.69; p=0.035), suggesting that sheep farmers exposed to OP pesticides were more vulnerable to increased psychological symptoms than the controls. The authors did not control for acute pesticide poisoning in their analysis. Bazylewicz-Walczak *et al* (1999) compared 26 greenhouse planting female workers occupationally exposed with OP pesticides with 25 women not exposed to pesticides before and after the spraying season. Exposed female workers displayed increased tension, greater depression and more frequent symptoms of CNS disturbances than the control group.

Steenland *et al* (2000) compared 191 current and former termiticide applicators applying chlorpyrifos over an average of 2.5 years to 189 unexposed controls (consisting of 100 friends of the exposed group and 89 North Carolina State employees). The exposed group reported more symptoms, including memory problems, emotional states such as tension (p=0.01), fatigue (p=0.0002) and loss of muscle strength than the unexposed group. An association was found between OP exposure and depression when compared to non-exposed friends (p=0.05), but no association when compared to state employees (p=0.55). The authors did not control for acute pesticide poisoning in their analysis.

Stallones and Beseler (2002) conducted a cross-sectional survey by among 761 farmers and their spouses in Colorado from 1993 to 1997. Exposure was measured by questionnaire documenting self-reported illness and depression was measured by Centre for Epidemiological Studies - Depression (CES-D). Findings showed that exposure to pesticides at high concentrations resulting in self-reported poisoning symptoms was significantly associated with high depressive symptoms independent of other known risk factors for depression among farm workers (OR=5.87, 95% CI:2.56-13.44).

Salvi *et al* (2003) conducted a descriptive cohort study of 37 workers involved in the farming of tobacco in Brazil who were exposed to OP pesticides and 25 of the original cohort who were assessed three months later during which time they had not been exposed. OP exposure was measured using a questionnaire and serum cholinesterase levels. Findings showed that of the 18 respondents diagnosed with psychiatric illness (13 with generalised anxiety disorder and 8 with major depression) the start of the study, the total number of psychiatric diagnoses decreased to 13 after three months without using OP pesticides. In addition, of the 12 respondents diagnosed with clinically significant extra-pyramidal symptoms, 10 participants still had significant Parkinsonism after three months without exposure to OP pesticides. Possible limitations to this study may have been a lack of a comparison group and a small sample size.

Beseler *et al* (2008) examined the relationship between diagnosed depression and pesticide exposure in male private pesticide applicators enrolled in the Agricultural Health Study between 1993 and 1997. Acute pesticide poisoning was more strongly associated with depression (OR = 2.57; 95% CI: 1.74-3.79) compared to intermediate (OR = 1.07; 95% CI: 0.87–1.31) or high (OR = 1.11; 95% CI: 0.87–1.42) cumulative exposure or an unusually high pesticide exposure event (OR = 1.65; 95% CI: 1.33–2.05). In the subgroup without a history of acute poisoning, high cumulative exposure was significantly associated with depression (OR = 1.54; 95% CI: 1.16-2.04).

An earlier study conducted by Levin *et al* (1979) where psychiatric manifestations were tested in commercial pesticide applicators and recently OP exposed farm workers. Elevated levels of anxiety were reported by the commercial pesticide applicators compared to controls. No difference was found between anxiety levels of farm workers recently exposed to OP pesticides and the control group. Beseler *et al* (2006) conducted a nested control study of 29074 female spouses of private pesticide applicators enrolled in the Agricultural Health Study from 1993 to 1997. After controlling for confounders, depression was significantly associated with a history of pesticide poisoning (OR = 3.26; 95% CI: 1.72-6.19). However, no association was found between depression and low (OR = 1.09; 95% CI: 0.91-1.31) or high (OR = 1.09; 95% CI: 0.91-1.31) cumulative pesticide exposure.

2.2.2.5 Biological plausibility between OP pesticide exposure and depression

Considerable evidence exists to suggest that alterations in the serotonergic neuronal function in the central nervous system play a role in the pathophysiology of depression in humans (Owens and Nemeroff, 1994; Resseler and Nemeroff, 2000). Further, drugs designed to restore serotonin synaptic function have been established as an effective therapy for the treatment of depression (Maes and Meltzer, 1995).

Data from animal studies suggest that OP pesticide effects are not restricted to the cholinergic system but rather involve a wide variety of neurotransmitters, notably serotonin (Raines et al, 2001; Aldridge et al, 2003; Slotkin et al, 2006). In animal models, the serotonergic pathway has been implicated in the development of depression-like behaviour (Aldridge *et al*, 2005; Chen *et al*, 2011; Lima *et al*, 2011) with some epidemiological studies demonstrating an association between OP pesticide exposure and depression (Stallones and Beseler, 2002; Salvi et al, 2003; Beseler *et al*, 2008). Given the role serotonin plays in the development of depression and the mechanism of action of OP pesticides through the serotonergic pathways in animal models, it seems plausible that OP pesticide exposure in humans may give rise to cognitive impairment i.e. depression mediated by the disruption of the serotonergic pathways.

2.2.3 Impulsivity

2.2.3.1 Definitions of impulsivity

Impulsivity may be regarded as a predisposition to action without reflection or regard for consequences (Moeller *et al*, 2001). Impulsivity can present in any individual with or without a DSM-IV axis I or II diagnosis, however it is more likely to present in individuals with certain psychiatric disorders, such as borderline and antisocial personality disorders, substance abuse or dependence, bipolar disorder and attention-deficit hyperactivity disorder (Moeller *et al*, 2001). The consequences of impulsivity may include substance abuse and suicidal behaviour (Moeller *et al*, 2001; Swann *et al*, 2005).

Eysenck and Eysenck (1977) related impulsivity to risk taking, lack of planning and making up one's mind quickly. Patton *et al* (1995) have categorized impulsivity into three components: acting on the spur of the moment (motor activation), not focusing on the task at hand (lack of attention) and not planning and thinking carefully (lack of planning).

2.2.3.2 Association between impulsivity, suicide and access to pesticides

Eddleston and Phillips (2004) postulated that easy access to highly toxic pesticides may turn "an impulsive act of self-poisoning into a suicide". Studies have proposed that the easy access to extremely toxic pesticides in the homes of the rural population throughout many low and middle income countries have made self-poisoning with pesticides the most common means of suicide with a very high case-fatality (Konradsen *et al*, 2003; Bertolote *et al*, 2006; Gunnell *et al*, 2007). Gunnell *et al* (2007) showed in an ecological study that placing restrictions on the import and sales of WHO Grade 1 toxicity pesticides in 1995 and endosulfan in 1998 was paralleled by reductions in suicide in both men and women of all ages in Sri Lanka. Van Spijker *et al* (2009) conducted a psychological autopsy of 19 survivors of 13 suicides due to pesticide poisoning in Nickerie, Surimane and found that impulsivity, aggression and easy accessibility of pesticides contributed towards fatal pesticide self-poisoning among South Asians.

2.2.3.2 Epidemiological studies on OP pesticides and impulsivity

Limited epidemiological studies were available to fully understand the role of OP exposure in suicide and impulsive behaviour. Pearson *et al* (2002) interviewed a sample of 147 women living in rural areas in China who were hospitalised for attempted suicide. The predominant method used by the respondents was poisoning with highly lethal pesticides and fertilizers (87.8%). Study findings showed that the respondents' suicide behaviour were characterised by high levels of impulsivity and low rates of mental illness, including depression, suggesting that suicide was, in this group, largely an act independent of any underlying affective illness.

An animal study in rats showed that repeated low level exposure to chlorpyrifos (an OP pesticide) may lead to prolonged impairment of sustained attention and an increase in impulsive behaviour as measured by the 5-choice serial reaction time task (5C-SRTT) (Middlemore-Risher *et al*, 2010).

2.3 Factors influencing mental health in farm workers

Several factors are highlighted in the literature as potential risk factors in the development of mental illness in farm workers. Risk factors included gender differences in mental illnesses, alcohol abuse and poverty (Bertolote *et al*, 2006; Beseler *et al*, 2006; Stallones and Beseler, 2002; London *et al*, 1997).

2.3.1 Gender risk differences

Throughout the world, women are at higher risk of developing mental illness than men. According to the World Health Organisation, depressive disorders account for close to 41.9% of the disability from neuropsychiatric disorders among women compared to 29.3% among men worldwide (Gender disparities in mental health, WHO). In an agricultural setting, depression among female farm workers were 2.67 times more likely than male farm workers in a study conducted by Stallones and Beseler (2002) in Colorado where depressive symptoms were measured using the centre for epidemiologic studies – depression (CES-D) scale. In the SASH study, South African women in the general population were 1.75 times more likely to experience lifetime depression than males and 2.17 times more likely to experience 12-month major depression episode than males (Tomlinson *et al*, 2009).

In contrast to depression, while the ratio of female-to-male suicides varies between countries, the global pattern of suicide is largely more common in men than women (Bertolote & Fleischmann, 2002), with the exception of China (Phillips & Zhang, 2002). In addition, more women worldwide are involved in acts of deliberate self-harm each year, with a female-to-male ratio of between 0.71:1 and 2.15:1 (median 1.5:1) (Platt *et al*, 1992). In the SASH study, women reported twice as many suicide attempts as men (3.8% (se=0.5) *v.* 1.8%

(se=0.3) (Joe *et al*, 2008). To date, there is no data available in South Africa on gender risk in agriculture for mental illness.

2.3.2 Alcohol abuse / dependence

Alcohol consumption and problems related to alcohol vary widely around the world, but the burden of disease and death remains significant in most countries. Alcohol consumption is the world's third largest risk factor for disease and disability, accounting for almost 4% of all deaths worldwide and is a causal factor in 60 types of diseases and injuries and is a component cause in 200 others (WHO, 2011).

South Africa is known to have one of the highest alcohol consumptions in the world per head for individuals who drink alcohol (Rehm *et al*, 2007). The lifetime prevalence of alcohol abuse and alcohol dependence in South Africa was 11.4% and 2.6% respectively (Stein *et al*, 2008). Historically, wine was paid to farm workers as partial payment for labour under what was called the "DOP" system. Ten years ago, the plight of the South African farm worker was highlighted in a study by London (2000) where evidence of the continued use of the DOP system was found.

2.3.3 Poverty

According to the World Health Organisation, 80% of persons with mental health conditions live in middle to low income countries (WHO, 2010). The WHO International Consortium of Psychiatric Epidemiology (2000) estimated that the highest prevalence of mental disorders can be found among people with the lowest levels of education or people who are unemployed. The interaction between poverty and mental ill-health has been described as a "vicious cycle" in which the conditions of poverty lead to high levels of stress, social exclusion, reduced access to social capital, malnutrition, obstetric risks, increased risk of violence, and thereby to increased prevalence and worse outcomes for mental disorders (Patel, 2001). In South Africa, poverty has been shown to be strongly associated with mental ill-health (Lund *et al*, 2008).

2.4 Difficulty in exposure characterisation in occupational health studies

Retrospective evaluation of exposure in occupational health studies is often open to recall and observer bias. Exposure misclassification continues to occur due to the lack of standardisation in the measurement of OP pesticide exposure across studies (ranging from questionnaire-based format to biological samples) thus making it difficult to compare study results (Sanborn *et al*, 2004).

An accurate estimation of exposure is critical for the validity and power of studies measuring long term health effects of OP pesticides. The use of a job exposure matrix (JEM) has been proposed as a method of characterising occupational exposure where biological monitoring data or industry records are unavailable or inaccurate (Hoar *et al*, 1980). Typically, a JEM makes use of a matrix with job history variables on one axis, chemical agents on the other and an estimate of exposure listed within the cells of the matrix, replacing the more traditional dichotomous (exposed or unexposed) or ordinal variable (high, medium, or low). London *et al* (1997) developed a JEM to characterise long term OP exposure in the agricultural workplace of 164 pesticide applicators and 83 non-exposed control workers from deciduous fruit farms in the Western Cape Province. Though the JEM provided greater accuracy of risk estimation and provided more information on the respondents' exposure, it was vulnerable to exposure misclassification (London & Myers, 1998).

2.5 Conclusion

It would appear from the epidemiological studies summarised above on suicide, depression and impulsivity that OP pesticide exposure may potentially play a role in the presence of increased depressive symptoms, impulsive behaviour and suicidal ideation in farm workers. However, there seems to be no clear consensus regarding the association of OP exposure with depression, impulsivity and suicide. In addition, very little epidemiological data was found on the role of impulsivity in suicide using pesticides. There remain considerable gaps in our knowledge especially with regard to South African farm workers and their vulnerability to mental illness. Given the increased use of OP pesticides in South Africa over past decade (Dalvie *et al*, 2009), further research is required to investigate the relationship between occupational exposure to chronic low dose OP pesticides and psychological outcomes.

CHAPTER THREE

3. Methodology

3.1 Overview

This chapter presents the methodology applied in this study. A primary analysis conducted by Major (2010) using logistic regression revealed no evidence of a positive association between OP pesticide exposure (both cumulative and current) and psychological effects on grape farm workers. The aim of the secondary analysis was to explore the relationship between exposure to low dose OP pesticides and depressive symptoms, impulsive behaviour and suicidal ideation of farm workers in the Western Cape using structural equation modelling (SEM); to test three models hypothesised as possible causal pathways between OP exposure and depression, impulsivity and suicide. As SEM has the advantage over a multiple regression technique by the ability to examine multiple relationships at a time (Hair *et al*, 2010), the use of this methodology hoped to provide a more rigorous and nuanced analysis of the exposure-outcome relationships than that achieved by Major (2010) in the study population. In addition we wished to assess the validity and reliability of the questionnaires used in the analysis.

3.1.1 Research design

A cross-sectional analytical study was conducted on adult farm workers on vineyards (table-grape and wine-grape farms) in a rural district about 100km from Cape Town in the Western Cape Province in June to August 2002.

3.1.2 Population and sampling

The study sampling procedure was described by Major (2010). A sample size of 776 was calculated, based on a power of 80%, a significance level (α) of 0.05, a 3:1 ratio of exposed to unexposed participants and an a priori estimate of the odds of OP pesticide exposure of 2:1. The research area included the farms surrounding the 4 towns of the Breede Valley: Rawsonville, Worcester, De Doorns and Touwsrivier. A random sample of 60 from 201 table-grape farms (affiliated to the Hex Valley Producers Association) was selected. From the random sample, 48 farms (80%) participated in the study. Due to limitations in access to wine-grape farms and farm workers, convenience sampling was undertaken to include 9 wine-grape farms. The data collected in 2002 included 817 adult farm workers employed on grape farms. This study, therefore, is a secondary data analysis of data collected using single-stage cluster sampling by farm.

3.2 Measurements

A survey questionnaire was used to collect demographic, socioeconomic, occupational exposure and risk factor data in the study. In addition, four instruments were utilised to measure psychiatric symptoms in the farming study population in 2002. The four neurobehavioural questionnaires used were the Barratt's Impulsivity Scale (BIS-11), Beck's Scale for Suicidal Ideation (SSI), the Brief Symptom Inventory (BSI) and the General Health Questionnaire (GHQ-28). All questionnaires were answered using a Likert scale and are explained below.

3.2.1 Instruments

3.2.1.1 Barratt's Impulsivity scale (BIS-11)

The Barratt's Impulsivity Scale version 11 (BIS-11) is a 30-item self-report questionnaire designed to assess the personality/behaviour construct of impulsiveness (Patton *et al*, 1995). The BIS-11 consists of three subscales: cognitive impulsiveness, motor impulsiveness and non-planning impulsiveness (Barratt, 1985). All items were answered on a four-point scale (rarely/never, occasionally, often and almost always/always). Items were scored from one to four, where four indicated the most impulsive response. The total score ranged from 30 to 120 and was calculated as the sum of the individual items or the sum of the three subscales. Although no established cut-off point exist for the BIS-11, Doran *et al* (2004) has suggested the use of the median of the BIS total score as a measure of high and low impulsivity. In this analysis, a score of more than and equal to 54 (the median) was used to categorise respondents as having impulsive behaviour.

Patton *et al* (1995) reported internal consistency coefficients of the BIS-11 questionnaire that ranged from 0.79 to 0.83 for study populations of undergraduate students, substance abuse patients, psychiatric inpatients and male inmates at a maximum security prison. The BIS-11 questionnaire has been applied in a South African study examining the violent behaviour and impulsivity of schizophrenic patients unable to stand trial (Kaliski and Zabow, 2005). No reliability data was published in this study.

3.2.1.2 Beck's Scale for Suicidal Ideation (SSI)

Beck's Scale for Suicidal Ideation (SSI) is a 21-item self-report questionnaire (only 19 items are scored) based on a semi-structured interview designed to quantify and assess suicidal intention (Beck *et al*, 1979). Each item consists of three alternative statements graded in intensity from zero to two. The total score ranged from 0 to 38 and was calculated as the sum of the individual item scores. No formal cut-off score has been established for the SSI. However, Beck and Steer (1991) highlighted that increasing scores reflected a higher suicide risk. In this analysis a total score of more than and equal to 1 (the median), was used to categorise respondents as having suicidal ideation.

The psychometric properties of the SSI scale have been investigated in both adult psychiatric inpatient and outpatients (Beck *et al*, 1979; Beck *et al*, 1988; Beck and Steer, 1991) and in adolescents (Steer, Kumar and Beck, 1993). The internal consistency of 90 psychiatric inpatients, as measured by Cronbach's alpha coefficient was 0.89, with an interrater reliability coefficient of 0.83 ($p<0.001$, Beck *et al*, 1979). In 1988, Beck *et al* compared the self-report SSI and clinically administered BSI total scores of 50 inpatients diagnosed with various psychiatric illness and 55 outpatients diagnosed with mood disorders using paper and pencil and computer administration of the questionnaire. There was a high correlation (0.90) between self reported and clinically-rated versions for both inpatients and outpatients, suggesting strong concurrent validity. The Cronbach's alpha coefficient for the paper-and-pencil version was 0.93 and computerised version was 0.97.

Beck's initial study (1979) used principal component analysis with varimax rotation of data from 90 inpatient suicide ideators to identify three dimensions: *active suicide behaviour*, *specific plans for suicide* and *passive suicide desire* (Beck *et al*, 1979). Subsequent factor analysis by Steer *et al* (1993) and Beck and Steer (1991) had only partially duplicated the findings by Beck (1979). In 1991, Beck and Steer demonstrated a five factor model for the SSI. Steer *et al* (1993) conducted a maximum-likelihood principal factor analysis with oblique rotation. Initially, five factors were identified. However two factors were removed as the factors consisted of fewer than 3 items each. The three retained factors represented *desire for death, preparation for suicide* and *active suicide desire*. No studies were identified in the literature that has been conducted using the SSI questionnaire in a South African population.

Preliminary SEM analyses using a single construct (total score) for the SSI resulted in poorly fitted SEM models. Therefore factor analysis using principal component factor extraction followed by a varimax rotation, following Beck's initial study in 1979, was applied to identify the underlying factor structure of the SSI questionnaire in order to enhance SEM model fit.

3.2.1.3 Brief Symptom Inventory (BSI)

The Brief Symptom Inventory (BSI) is a 53-item self-report symptom inventory designed to reflect the psychological symptom patterns of psychiatric and medical patients and non-patients (Derogatis, 1993). The nine primary symptom subscales are: somatisation, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation and psychoticism. The Global Indices include: Global Severity Index (GSI) that measures overall *psychological distress* level; Positive Symptom Distress Index (PSDI) that measures the intensity of symptoms and the Positive Symptom Total Index (PSI) that reports the number of self-reported symptoms. The BSI instrument provides an overview of a patient's symptoms and their intensity at a specific point in time. Each item is rated on a five point scale of distress (zero to four), ranging from not at all to extremely (Derogatis and Meliseratos, 1983). According to Deragatis (1993), the GSI is regarded as the single most sensitive indicator of severity of disorder. The GSI raw score is calculated from the sum of the nine subscales plus the additional items divided by the total number of responses i.e. 53, when there are no missing values. The GSI score is then converted to a t-score based on the standard adult non-patient male and female norms (Derogatis, 1993). Participants were categorised as having *psychological distress,* based on standard t-scores of the GSI where the cut-off score was more than and equal to 63 ($T_{GSI} \geq T_{63}$) (Derogatis, 1993).

Derogatis and Meliseratos (1983) described the internal consistency of the nine BSI subscales ranging from 0.71 to 0.85 in a sample of 1002 psychiatric outpatients. Test-retest reliability estimates ranged from 0.68 to 0.91 over a two-week period. The BSI questionnaire has been used in international agriculture settings investigating psychological symptoms in farm workers exposed to OP pesticide (Solomon *et al*, 2007; Wesselling *et al*, 2010); however reliability data was not available. The BSI has been applied in a South African male university population examining the long term effects of child sexual abuse (Collings, 1995). No reliability data was published in this study.

3.2.1.4 General Health Questionnaire (GHQ-28)

The General Health Questionnaire is a self-administered, 28-item questionnaire designed as a screening tool for non-psychotic psychiatric disorders and assesses four subscales: somatic symptoms, anxiety and insomnia, social dysfunction and severe depression (Goldberg and Hillier, 1979). Each item was answered on a four-point scale (not at all, no more than usual, rather more than usual and much more than usual) scoring from zero to three. The total score, the sum of the individual items or sum of the four subscales, ranged from 0 to 84. A cut-off score of more than and equal to 24 was used to categorise respondents as having psychological symptoms (Goldberg *et al*, 1997). All four subscales were used initially in the SEM analysis as a proxy measure of depression. Thereafter selected models were evaluated using only the depression subscale in the SEM analysis.

Versions of the GHQ have been available using 12, 28, 30 and 60 items. A validity study of GHQ-12 and GHQ-28, conducted across 15 centres and translated into 10 languages, revealed an average area under the ROC curve of 0.88, ranging from 0.83 to 0.95 (Goldberg *et al*, 1997). The stability of the factor structure of the GHQ-28 by Werneke *et al* (2000) revealed factors expressing depression and social dysfunction were more stable than factors expressing somatic and anxiety symptoms.

Versions of the GHQ have been used in agricultural settings internationally (Booth and Lloyd, 2000) and specifically in relation to OP exposure and depression (Stephens *et al*, 1995; Zhang *et al*, 2009). The GHQ-28 has also been applied in South African urban settings (Michealowsky *et al*, 1989, Spangenberg and Pieterse, 1995). A South African agricultural study by (Steenkamp *et al*, 2005) evaluated exposure to violence, quality of life and health status in 52 farm workers. Findings revealed an average exposure to violence, low quality of life and sub-average health status. However, no reliability data has been published from these studies.

3.2.2 Variables

Variables tested in the hypothesised models are defined below, including variables related to exposure, outcome and confounding variables.

3.2.2.1 Exposure variables

Exposure variables were characterised from an occupational and environmental health questionnaire that utilised an approach based on a job-exposure matrix (JEM) applied in past occupational health studies amongst South African farm workers (London *et al*, 1998). Factors used for the JEM included eight specific pesticide applicator / farming activities and are listed below. The cumulative years spent in each activity were calculated and a time-exposed variable was assigned for each pesticide applicator activity (measured in years).

The following eight pesticide applicator activities included:

a) spraying OP pesticides from the back of a tractor
b) spraying OP pesticides using a backpack
c) exposure to OP pesticides while dipping livestock
d) hand spraying OP pesticides
e) employed for general maintenance farm work on the vineyard
f) gardening
g) harvesting grapes
h) employed for farm work on orchards

In the study sample, male participants were involved in all eight farming / spraying activities (a - h). However, female participants were limited to five specific tasks (d – h). In addition, an OP exposure variable was calculated for each participant, measuring cumulative years worked in the agricultural sector *(OPtotal)*. Exposure variables were classified as continuous variables, with skewed (non-normal) distributions.

3.2.2.2 Outcome variables

The outcome variables used in this analysis were depressive symptoms, impulsive behaviour and suicidal ideation. The total BSI and GHQ-28 scores measured psychological symptom patterns. Participants categorised as having psychological distress, were dichotomised based on the GHQ-28 total score (GHQ-28 ≤ 23; GHQ-28 ≥ 24) and on the standard t-scores of the GSI of the BSI for male and female participants ($T_{GSI} < T_{63}$; $T_{GSI} \geq T_{63}$). Participants categorised as having impulsive behaviour were dichotomised based on the median BIS-11 total score (BIS-11 ≤ 53; BIS-11 ≥ 54). Participants categorised as having suicidal ideation were dichotomised based on the median SSI total score (SSI < 1; SSI ≥ 1).

The total BSI score was used in the exploratory analysis when describing the proportion of the respondents categorised as having psychological symptoms. However, due to a high number of zero counts in the depression subscale (381, 50.7%), the nine BSI symptom dimensions / subscales were used in the SEM analysis as a proxy measure for depression. As described with the BSI questionnaire, the total GHQ-28 scores were used to measure the proportion of psychological symptom patterns among respondents. The four subscales of the GHQ-28 questionnaire were used in the SEM analysis as a proxy measure of depression instead of the severe depression subscale due to a high number of zero counts in the severe depression subscale (408, 54.3%).

Total scores and subscales for each instrument were included in the analysis and were classified as continuous variables. Table 3.1 summarises the variables included into the multivariate analysis. The individual items were scored as Likert scales. The distributions of the total and subscale scores were skewed.

3.2.2.3 Confounding variables

Based on the associations reported in the literature on the mental health outcomes, factors included as confounders in the assessment of the three models in the analysis were: age, gender, a history of past OP poisoning, CAGE score and a socioeconomic score. Age (measured in years) was classified as a continuous variable. Gender was classified as a dichotomous variable (0=female, 1=male). A history of past OP poisoning was classified as a dichotomous variable from the following question “Have you ever been sick from pesticides?" as (0= no history of past OP pesticide poisoning, 1= history of past OP pesticide poisoning).

A socioeconomic score was derived from a household score of ownership of 7 different commodities (1 point for each commodity; range 0-7). The commodities included owning a bath, shower, electricity, refrigerator, television, radio and a telephone. The score was reclassified into a dichotomous variable (0 = [low SES] possession of fewer than four items; 1 = [high SES] possession of four or more items).

The CAGE assessment consists of the following four questions (Ewing, 1984):

- Have you ever felt that you should cut down on your drinking?
- Have people annoyed you by criticising your drinking?
- Have you ever felt bad or guilty about your drinking?
- Have you ever had a drink first thing in the morning to steady your nerves or to get rid of a hangover?

Item responses on the CAGE are scored zero or one, with a total score of two or greater considered clinically significant. The CAGE score was reclassified into a dichotomised variable (0 = less than two indicated no alcohol-related problems; 1 = more than and equal to two indicated alcohol-related problems, referred to as a 'positive' CAGE score). The CAGE questionnaire has been applied in South African urban populations (Claassen, 1999; Townsend *et al*, 2010) and South African farming populations (London *et al*, 1997; London, 2000).

Table 3.1 Variables used in the analysis

Variable name	Measured by	Type of variable
Exposure variables		
Spraying from the back of a tractor	OP1 (years)	continuous
Hand spraying pesticides	OP2 (years)	continuous
Spraying pesticides using a backpack	OP3 (years)	continuous
Maintenance work	OP4 (years)	continuous
Gardening	OP5 (years)	continuous
Harvesting	OP6 (years)	continuous
Dipping livestock	OP7 (years)	continuous
Orchard work	OP8 (years)	continuous
Cumulative years exposed	OP total (years)	continuous
Confounding variables		
Age	age (years)	continuous
Gender	0 = female, 1 = male	categorical
Past history of OP pesticide poisoning	0 = no past history of OP poisoning, 1= past history of OP poisoning	categorical
Socioeconomic score	0 = lower, 1 = higher	categorical
CAGE score	0 = negative, 1 = positive	categorical
Outcome variables		
Depressive symptoms		
GHQ-28		
GHQ subscale A (somatic symptoms)	DS1	continuous
GHQ subscale B (anxiety and insomnia)	DS2	continuous
GHQ subscale C (social dysfunction)	DS3	continuous
GHQ subscale D (severe depression)	DS4	continuous
GHQ case	GHQ total ≥ 24	categorical
BSI		
BSI subscale A (somatisation)	BSI1	continuous
BSI subscale B (obsessive-compulsive)	BSI2	continuous
BSI subscale C (interpersonal sensitivity)	BSI3	continuous
BSI subscale D (depression)	BSI4	continuous
BSI subscale E (anxiety)	BSI5	continuous
BSI subscale F (hostility)	BSI6	continuous
BSI subscale G (phobic anxiety)	BSI7	continuous
BSI subscale H (paranoid ideation)	BSI8	continuous
BSI subscale I (psychotism)	BSI9	continuous
BSI case	$T_{GSI} \geq T_{63}$	categorical
Impulsive behaviour		
BIS-11		
BIS subscale A (attention)	IB1	continuous
BIS subscale B (motor)	IB2	continuous
BIS subscale C (non-planning)	IB3	continuous
BIS-11 case	BIS-11 total ≥ 54	categorical
Suicidal ideation		
SSI		
SSI factor 1 (desire for death)	SIa	continuous
SSI factor 2 (preparation for suicide)	SIb	continuous
SSI factor 3 (active suicide desire)	SIc	continuous
SSI case	SSI total ≥ 1	categorical

3.3 Statistical methods

3.3.1 Introduction to structural equation modelling

Structural equation modelling is one of the most widely used statistical techniques in social science, especially in psychology. SEM is described as a family of statistical models that seek to explain the relationships among multiple variables and as a comprehensive statistical approach to testing hypotheses about relations among observed and latent variables (Hair, 1999; Hoyle, 1995). In short, SEM is a multivariate technique that is used to examine complex relationships.

SEM was selected as the statistical methodology because of its several advantages over regression modeling. These include the use of confirmatory factor analysis to reduce measurement error by having multiple indicators per latent variable, better model visualization through its graphical modeling interface, desirability of testing models overall instead of coefficients individually, the ability to test models with multiple dependents and the ability to model mediating variables rather than be restricted to an additive model in regression analysis (Hair, 2010; Hoyle, 1995).

Latent variables or constructs, defined as hypothetical or unmeasured variables, are utilised in situations where constructs are not directly measurable (Hair *et al*, 2010). There are two components to SEM modelling: a measurement model and the structural model. The measurement model defines how the constructs are related to or formed from the input variables. The structural model defines the causal pathway i.e. the relationships between the different constructs. Exogenous constructs are latent variables that are independent and are determined by factors outside the model. Endogenous constructs are dependent latent variables and are theoretically determined by factors within the model (Hair *et al*, 2010). Table 3.2 summarises the endogenous and exogenous variables used in the SEM analysis for this study. The commonest graphical representation of a structural equation model is a path diagram as shown in figure 3.1.

Table 3.2 Summary of endogenous and exogenous constructs used in the SEM analysis

Exogenous constructs	Endogenous constructs
Age	Depressive symptoms
OP pesticide exposure	Impulsive behaviour
History of past OP pesticide poisoning	Suicidal ideation
Socioeconomic score	
CAGE score	

3.3.2 Estimating relationships using path analysis

Path analysis calculates the strength of the relationships using only a correlation or a covariance matrix as input (Hair *et al*, 2010). Path diagrams play a functional role in structural equation modelling. It represents a visual portrayal of the hypothesised model. In a path diagram, circles or ovals represent latent variables and boxes represent directly measured variables. A straight single-headed arrow represents a regression path and a curved path represents a correlation estimate or covariance. Path coefficients are displayed as standardised regression coefficients and quantify the magnitude of a correlation between constructs.

The relationships hypothesised for this study was derived from a review by London *et al* (2005). Based on their review, exposure to OP pesticides was suggested as part of a possible etiological pathway that leads to suicide, where this pathway may be mediated by either symptoms of depression (model 1), impulsive behaviour (model 2) or both (model 3); see figure 1.1, page 22.

Figure 3.1 portrays a structural model that describes the relationship between OP pesticide exposure and depression, impulsivity and suicidal ideation for model 3. In this diagram, L_i represents the factor loadings between the measured and latent variables and $P_{j,k}$ represents the regression coefficient between the latent variables j and k in the model.

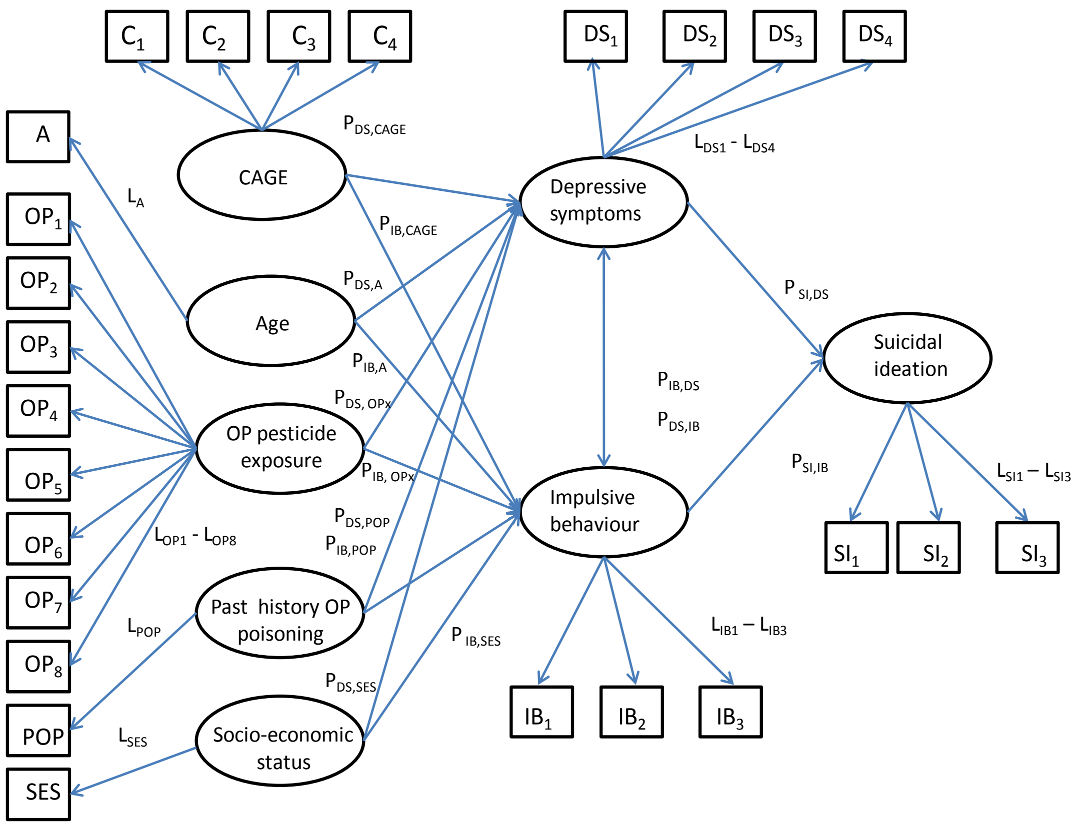

Figure 3.1 Path diagram showing specified hypothesised structural relationships and measurement specification (error terms not shown)

3.3.3 Mathematical modelling

Underlying the graphical model, illustrated in Figure 3.1, are systems of measurement and structural equations. The hypothesised model 3 (figure 3.1) is expressed below in regression coefficient notations.

Table 3.3 Exogenous indicators of the measurement model with regression coefficients and error terms

Exogenous indicators	Exogenous constructs	Regression coefficients	Error terms
age	Age	L_A	e_A
OP1-OP8, OP total	OP exposure	L_{OP1} - $L_{OPtotal}$	$e_{OP1\text{-}OPtotal}$
POP	Past history of OP poisoning	L_{POP}	e_{POP}
SES	socioeconomic score	L_{SES}	e_{SES}
cage1-cage4	CAGE score	$L_{cage1\text{-}cage4}$	$e_{cage1\text{-}cage4}$

Table 3.4 Endogenous indicators of the measurement model with regression coefficients and error terms

Endogenous indicators	Endogenous constructs	Regression coefficients			Error terms
		Depressive symptoms	Impulsive behaviour	Suicidal ideation	
DS_1	Depressive symptoms	L_{DS1}			e_{DS1}
DS_2		L_{DS2}			e_{DS2}
DS_3		L_{DS3}			e_{DS3}
DS_4		L_{DS4}			e_{DS4}
IB_1	Impulsive behaviour		L_{IB1}		e_{IB1}
IB_2			L_{IB2}		e_{IB2}
IB_3			L_{IB3}		e_{IB3}
SI_1	Suicidal ideation			L_{SI1}	e_{SI1}
SI_2				L_{SI2}	e_{SI2}
SI_3				L_{SI3}	e_{SI3}

Table 3.5 Structural model with regression coefficients and error terms

Structural constructs	Depressive symptoms	Impulsive behaviour	Error terms
Age	$P_{DS,A}$	$P_{IB,A}$	e_A
OP pesticide exposure	$P_{DS,OPx}$	$P_{IB,OPx}$	$e_{OP1\text{-}OPtotal}$
Past OP pesticide poisoning	$P_{DS,POP}$	$P_{IB,POP}$	e_{POP}
Socioeconomic score	$P_{DS,SES}$	$P_{IB,SES}$	e_{SES}
CAGE score	$P_{DS,CAGE}$	$P_{IB,CAGE}$	e_{CAGE}
Depressive symptoms	–	$P_{IB,DS}$	E_{DS}
Impulsive behaviour	$P_{DS,IB}$	–	E_{IB}
Suicidal ideation	$P_{SI,DS}$	$P_{SI,IB}$	E_{SI}

3.3.4 Data management

The original dataset (n=817) was exported from SPSS (SPSS for Windows, Chicago: SPSS Inc, 2001) into STATA statistical package version 10 (StataCorp, Texas, USA, 2007) for exploratory analysis where appropriate examination and cleaning of the dataset was done. Missing data (n=65) was identified for the following variables: 58 (7.1%) missing observations on past history of OP pesticide poisoning, 6 (0.7%) missing observations on age and 1 (0.1%) missing observation on the total suicide ideation score. Missing data was removed by a listwise deletion procedure reducing the sample size to 752. The study sample was then compared to the excluded participants to evaluate whether bias may have been introduced when the 65 participants were removed from the dataset. Outliers were identified graphically through univariate detection by boxplots and bivariate detection by scatterplots of pairs of variables.

The data was examined to test the validity of the assumptions underlying the chosen multivariate analysis. These included multivariate normality, independence, random sampling and linear associations. Linearity was assessed by examining scatter plots of the variables to detect nonlinear patterns in the data. The graphical and statistical tests assessing the assumptions for multivariate analysis revealed independence, linearity of the variables and random sampling. However, the data was significantly skewed and deviated from multivariate normality. The dataset was thereafter exported into LISREL 8.8 (Scientific Statistical Software, 2007) for confirmatory factor analysis of Beck's suicidal ideation scale and structural equation modelling.

3.3.5 Statistical analysis

Exploratory data analysis was conducted using STATA (version 10) statistical software (StataCorp, Texas, USA, 2007). The survey design was specified with farms as the cluster variable. Non-normally distributed continuous variables were presented using median and inter-quartile range (IQR) and compared using Wilcoxon rank-sum (Mann-Whitney) test. Categorical variables were presented as frequencies and percentages. Chi-square tests were used for between-group comparisons of categorical variables. Correlations among the continuous variables were assessed by Spearman rank correlation coefficient. Agreement between the BSI and GHQ-28 questionnaire was measured using the kappa statistic.

The multivariate analyses was conducted on a sample of male farm workers only (n=447) due to the difference in pesticide exposure activities between genders. Multivariate analyses included factor analysis of the SSI, reliability analysis of the four instruments and structural equation modelling.

Factor analysis of the SSI was conducted using principal component factor extraction with varimax rotation. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was calculated in order to determine the degree of inter-correlations among the variables and the appropriateness for factor analysis. This index ranges from 0 to 1, reaching 1 when each variable is perfectly predicted without error by other variables. This measure can be interpreted with the following guidelines: 0.80 or above, meritorious; 0.70 or above, middling; 0.60 or above, mediocre; 0.50 or above, miserable and less than 0.50, unacceptable (Kaiser, 1970). Factor selection criteria were based on the latent root criterion, percentage of variance, a priori where a predetermined number of factors were selected based on prior research and the scree test criterion. For each variable, factor loadings of more than 0.40 were considered significant based on sample size criteria (Hair *et al*, 2010). Communalities of the variables were assessed. The summated scales were calculated by summing the items comprising of the new factors. The dimensionality of each scale was supported by the high factor loading of each variable on one factor. The internal reliability of the new factors was measured by Cronbach's alpha coefficients.

The internal consistency of the four scales (BIS-11, SSI, BSI, GHQ-28) was measured in three ways: item-to-total correlations (correlation of the item to the summated scale score), inter-item correlation and Cronbach's alpha coefficient. Cronbach's alpha coefficient is an internal reliability measure which ranges from zero (no internal consistency) to one (perfect internal consistency). A Cronbach's alpha coefficient of more than and equal to 0.70 was considered "adequate" and more than 0.8 was considered "good" (Hair *et al*, 2010).

Confirmatory factor analysis (CFA) and structural equation modelling was conducted with LISREL 8.8 (Scientific Statistical Software, 2007). Hair *et al* (2010) describes the SEM model building process in six stages: defining the individual constructs, developing the overall measurement model, designing a study to produce empirical results, assessing the measurement model validity, specifying the structural model and assessing the structural model validity.

a) Defining the individual constructs

   The scales used to measure depressive symptoms; impulsive behaviour and suicidal ideation were based on previous published research and scored in the Likert format (Barratt, 1985; Beck, 1979; Derogatis, 1993; Goldberg *et al*, 1997).

b) Develop and specify the measurement model

Having specified the scaled items, the measurement model was specified. In this stage each latent construct in the model was identified and the measured indicator variables were assigned to the latent constructs. The measurement model is shown in SEM notation in table 3.3 and 3.4. The unidimensionality and the number of indicators per construct were assessed. Unidimensionality measures are a set of measured variables that can be explained by only one underlying construct. Constructs are considered "*identified*" when three or more items represent a factor (Hair *et al*, 2010). OP pesticide exposure consisted of eight measured items (farming / pesticide applicator activities) as well as a single-item construct (*OPtotal*). Depressive symptoms consisted of four and nine measured items from the GHQ-28 and BSI subscales respectively; impulsive behaviour and suicidal ideation consisted of three measured items. Variables age, history of past pesticide poisoning and socioeconomic score were single-item constructs that were considered *under-identified.*

c) Design a study to produce empirical results

This stage focused on the type of data analysed, the impact and remedies of missing data, model estimation and the impact of sample size. Metric and non-metric data were incorporated into the SEM model. Covariance matrixes were used as input for the analysis. Missing data was identified; reducing the sample size to 752 after list-wise deletion was applied. A general recommendation for adequate sample size is 10 participants for every free parameter set (Hair, 2010, Hoe, 2008). In addition, Hair *et al* (2010) recommended a minimum sample size of 300 for models with seven or fewer constructs, lower communalities (less than 0.45) and multiple under-identified (less than three items) constructs. Due to the increasing complexity from models 1 to 3, participants per free parameter estimated ranged from 6 to 8 for model 3 which was less than the recommended 10 participants per free parameter. Therefore the sample size for male farm workers (n=447) used in the analysis could be considered adequate for only models 1 and 2 with seven constructs, of which three were under-identified. The method of model estimation used was robust maximum likelihood estimation due to multivariate non-normality.

d) Assess measurement model validity

Measurement model validity depends on goodness-of-fit for the measurement model. Goodness-of-fit (GOF) indicates how well the specified model reproduces the observed covariance matrix among the indicator items. GOF is assessed by absolute, incremental and parsimonious fit indices. Absolute fit measures used in the analysis include the chi-squared (χ^2) GOF with a p-value and degrees of freedom and the root mean square error of approximation (RMSEA) with a confidence interval. An incremental fit measure used was the comparative fit index (CFI) and parsimony fit index included the parsimony normed fit index (PNFI). Suggested threshold cut-off values are as follows: low χ^2 with an insignificant p-value (Hair *et al*, 2010); a ratio of chi-square by degrees of freedom (χ^2/df) less than 3 (Kline, 2005); RMSEA < 0.08 (Kline, 2005); CFI > 0.90; NNFI > 0.90 and when comparing one model to another, the highest PNFI value indicates better fit (Hair *et al*, 2010).

e) Specify the structural model

Using model 3 as an example, the following structural relationships were assigned based on the theory proposed by London *et al* (2005):

H1: OP pesticide exposure is positively associated with both depressive symptoms and impulsive behaviour;

H2: There is an interaction between depressive symptoms and impulsive behaviour which modifies the risk for suicide in male farm workers.

f) Assessing the structural model validity

The final stage involved testing the structural models GOF and examining the individual parameter estimates. The GOF estimates and threshold cut-offs were discussed in (d). Parameter estimates were examined for values that are statistically significant (p<0.05) and in the predicted direction i.e. more than zero for a positive relationship. Standardised loading estimates of 0.50 or larger confirm that the indicators are strongly related to their associated constructs and can be an indication of construct validity (Hair *et al*, 2010).

3.4 Limitations

Study design and methodological study limitations were considered. A disadvantage of a cross-sectional study is the difficulty in establishing the correct temporal relationship between exposure (OP pesticide) and outcomes (depression, impulsivity and suicide), where the exposure status and disease status are measured together. Therefore compared to cohort and case-control studies, a cross-sectional design provides weaker information regarding causation. Exposure misclassification occurs when an exposed participant is classified as unexposed and vice versa, and has a potential to increase random error, if non-differential or to bias results if differentially distributed. Variation in exposure to OP pesticides among the pesticide applicators over time may also result in non-differential variability when interpreting the results. In addition, possible reporting bias due to the use of self reported questionnaires for depression, impulsivity and suicidal ideation may have been introduced.

Under-identified constructs i.e. one- and two- item factors have the potential to develop identification and estimation problems. These include "Heywood cases" and/or illogical standardised path estimates. Negative error variances or "Heywood cases" can arise in factor analysis and SEM because of presence of outliers, non-convergence of the models, under-identification of the constructs, structurally misspecified models or sampling fluctuations (Kolenikov and Bollen, 2007). A standardised path estimate ranges between zero and one. An illogical standardised path estimate is when the estimate is more than one or less than zero. A Heywood case is defined as a negative error variance and can be found in circumstances in factor analysis when the sample size is too small or too many factors extracted. Three single-item constructs in each model increased the possibility of developing identification and estimation errors. Subsequently, the models containing the female farm worker data subset presented Heywood cases and were removed from the SEM analysis. The models presented in the following chapter include only the male farm worker data subset.

3.5 Ethical considerations

Ethics approval for the original study was obtained from the UCT Research Ethics Committee (reference number: 104/99). This thesis was a secondary analysis of a cross sectional study done in 2002. All data were re-coded by the primary researcher preventing identifying links to any individual participant, thereby ensuring study participant anonymity. The original questionnaires were not accessed and therefore confidentiality remained assured.

CHAPTER FOUR

4. Results

4.1 Introduction

This chapter presents the results of the study. The data is presented in three parts: descriptive analysis of the sample; bivariate analysis of the exposure, outcome and confounding variables and multivariate analysis.

4.2 Description of the sample

The original sample consisted of 817 study participants. The sample size was reduced to 752 by list-wise deletion of missing data (n=65). All metric variables followed a non-normal distribution. All statistical inference took clustering by farms into account.

Table 4.1 compares the study sample (n=752) to the excluded study participants (n=65) to check whether bias was introduced during the selection of the study sample. There was no difference in the gender distribution and the socioeconomic score between the study sample and the excluded study participants. The OP exposure profile of the farm workers differed between the two groups. Respondents in the study sample were exposed to OP pesticides over significantly longer duration than the excluded participants while employed for maintenance farm work, harvesting and cumulatively.

Psychological distress was measured by the GHQ-28 and the BSI questionnaire. There was no difference in the levels of psychological distress reported by the study sample and the excluded study participants as measured by the GHQ-28 questionnaire. However, study respondents reported significantly higher levels of psychological distress when measured by the BSI questionnaire compared to the excluded participants. There was no difference in the levels of depression between the study sample and the excluded respondents for both GHQ-28 and BSI subscales of depression. The excluded participants reported significantly higher levels of impulsive behaviour than the study sample.

From the analysis above, there appeared to be differences between OP exposure and the mental health profile of the study sample compared to the excluded participants. Though the excluded participants was small and constituted approximately 8% of the original sample, bias may have been introduced when participants were excluded on the basis of incomplete data.

Table 4.1 Descriptive profile of the study sample (n=752) compared to the excluded participants (n=65)

Variable	**Study sample**	**Excluded participants with missing observations**	**p-value**
Population (n, %)	752 (92.1)	65 (7.9)	-
Gender			
Male (n, %)	447 (59.4)	39 (60)	
Female (n, %)	305 (40.6)	26 (40)	0.930 [a]
Socioeconomic score			
Lower (n, %)	279 (37.1)	26 (40)	
Higher (n, %)	473 (62.9)	39 (60)	0.643 [a]
Pesticide applicator / farming activities (measured in years)			
Hand spraying pesticides (med, IQR)	3 (0-7)	0 (0-5)	0.179 [b]
Maintenance work (med, IQR)	7 (3-15)	5 (1-10)	0.007 [b]
Gardening (med, IQR)	0 (0-5)	0 (0-5)	0.886 [b]
Harvesting (med, IQR)	7 (3-14)	5 (1-10)	0.020 [b]
Orchards (med, IQR)	4 (0.25-11)	3 (0-9)	0.115 [b]
Cumulative years exposed (med, IQR)	11 (6-19.3)	9 (3-15)	0.017
Measures of psychological distress			
GHQ-28 total score (med, IQR)	14 (10-20)	14 (10-18)	0.576 [b]
BSI total score (med, IQR)	18 (7-32)	10 (4-23)	0.007 [b]
Measures of depression			
Severe depression subscale (med, IQR)	1 (0-2)	1 (0-2)	0.535 [b]
Depression subscale (med, IQR)	1 (0-2)	1 (0-2)	0.557 [b]
Measures of impulsive behaviour			
BIS-11 total score (med, IQR)	54 (46–61.5)	61 (56-66)	< 0.001 [b]

a - Pearson chi-squared p-value, b - Wilcoxon rank-sum (Mann-Whitney) p-value

4.2.1 Socio-demography

Of the remaining 752 study participants, 447 (59.4%) were male and 305 (40.6%) were female. The median age of the participants was 33.3 years (IQR, 27 to 42 years). Two hundred and seventy nine (37.1%) participants had a low socioeconomic score based on owning less than four out of seven commodities (chapter three, section 3.2.2.3; page 43).

4.2.2 OP pesticide exposure

Exposure to OP pesticides was derived from the following eight farming / pesticide applicator tasks: spraying from the back of a tractor, hand spraying, spraying using a backpack, exposure while working in an orchard, harvesting, gardening, employed for maintenance farm work and dipping livestock. The time spent in each task was measured in years. Two OP exposure measures were used in the SEM analysis i.e. the cumulative years exposed while employed in the agricultural sector (*totalOP*); and the time exposed performing any of the eight spraying / farming activities, combined into one measure.

Male farm workers were involved in all eight pesticide applicator / farming activities whereas the female farm workers were only involved in the following five pesticide applicator activities: hand spraying, exposure while working in an orchard, harvesting, gardening and employed for maintenance farm work. Tables 4.2 and 4.3 summarises the prevalence of exposure of each activity and the median and inter-quartile range (IQR) of the time exposed to OP pesticides for male and female farm workers respectively.

Pesticide-specific applicator tasks carried out by male farm workers included spraying from the back of a tractor, spraying from a back pack and dipping of livestock. Both male and female farm workers were engaged in hand spraying pesticides. Approximately 40% of male farm workers sprayed pesticides from the back of a tractor and from a back pack. Approximately 20% of male farm workers were engaged in dipping livestock. Over 70% of male farm workers were involved hand spraying pesticides compared to 35% of female farm workers.

Thus the predominant occupations leading to exposure summarised in tables 4.2 and 4.3 were maintenance work, harvesting and working in the orchards for both males and females. In addition, most males were also exposed whilst hand spraying pesticides.

Table 4.2 Prevalence of exposure, median and inter-quartile range of OP exposure variables in male farm workers (n=447)

OP pesticide exposure variables (years)	Prevalence of exposure (n, %)	Median (IQR)
Spraying from the back of a tractor	131 (43)	0 (0-4)
Hand spraying pesticides	346 (77.4)	2 (0-10)
Spraying pesticides using a backpack	196 (43.8)	0 (0-7)
Maintenance work	420 (94)	7 (3-15)
Gardening	210 (45)	0 (0-7)
Harvesting	406 (90.8)	7 (3-15)
Dipping livestock	94 (21)	0 (0-0)
Orchards	346 (77.4)	5 (0.7-12)

Table 4.3 Prevalence of exposure, median and inter-quartile range of OP exposure variables in female farm workers (n=305)

OP pesticide exposure variables (years)	Prevalence of exposure (n, %)	Median (IQR)
Hand spraying pesticides	107 (35.1)	0 (0-4)
Maintenance work	291 (95.4)	7 (3-14)
Gardening	72 (23.6)	0 (0-0)
Harvesting	284(93.1)	7 (3-13)
Orchards	219 (71.8)	4 (0-10)

Table 4.4 compares the five OP pesticide applicator / farming tasks shared by male and female farm workers using the two-sample Wilcoxon rank-sum (Mann-Whitney) test. The length of time farm workers were exposed to OP pesticides while employed for maintenance, harvesting and orchard farming activities were comparable between the genders. Male farm workers were cumulatively exposed to OP pesticides over a longer duration than female farm workers (13 years [IQR 6-22.4 years] vs. 10 years [IQR 10 (5-17), p<0.001). In addition, male farm workers were exposed to OP pesticides over significantly longer duration with regard to hand spraying (2 years [IQR 0-10 years] vs. 0 years [IQR 0-4 years], p<0.001) when compared to female farm workers. Male farm workers had significantly higher mean exposure time to OP pesticides while gardening when compared to female farm workers (4.99 years [SD = 8.59 years] vs. 2.33 years [SD = 5.46 years], p<0.001).

Table 4.4 Comparison of OP pesticide exposure variables between male and female farm workers (n=752)

OP pesticide exposure variable (measured in years)	Males		Females		p-value[#]
	median (IQR)	mean (SD)	median (IQR)	mean (SD)	
Hand spraying pesticides	2 (0-10)	6.36 (9.06)	0 (0-4)	3.12 (5.89)	<0.001
Maintenance work	7 (3-15)	10.16 (9.60)	7 (3-14)	8.95 (7.76)	0.439
Gardening	0 (0-7)	4.99 (8.59)	0 (0-0)	2.33 (5.46)	<0.001
Harvesting	7 (3-15)	9.81 (9.58)	7 (3-13)	8.86 (7.80)	0.761
Orchards	5 (0.7-12)	8.09 (9.32)	4 (0-10)	6.65 (7.37)	0.111
Cumulative years exposed	13 (6-22.4)	15.23 (11.40)	10 (5-17)	11.94 (8.62)	<0.001

- Wilcoxon rank-sum (Mann-Whitney) p-value

4.2.3 Outcomes

The mental health outcomes of the study sample are summarised in table 4.5. Psychological distress was measured by the GHQ-28 and the BSI. The study participants had a median GHQ-28 total score of 14 (IQR, 10-20) and a median BSI total score of 18 (IQR, 7-32). The proportion of the study population categorised as having of psychological distress based on the two instruments were: 18.6% (140) of participants on the GHQ-28 (cut-off score ≥ 24; Goldberg, 1997) and 22.5% (169) of participants based on the standard t-scores of the global severity index (T_{GSI}) of the BSI (cut-off score ≥ T_{63}; Derogatis, 1993).

The BIS-11 questionnaire had a median total score of 54 (IQR, 46-61.5). Three hundred and eighty one (50.7%) participants were categorised as having impulsive behaviour based on the BIS-11 (median cut-off score ≥ 54).

Study participants reported a low median for the SSI total score of 1 (IQR, 0 to 2), in addition to a large proportion of zero counts (372, 49.7%) as shown in figure 4.1. The proportion of study participants categorised as having suicidal ideation were 50.5% (380) based on the SSI (median cut-off score ≥ 1).

Table 4.5 Summary of GHQ-28, BSI, BIS-11 and SSI questionnaires (n=752)

Questionnaires	Median (IQR)
GHQ-28	
Somatic symptoms subscale	3.5 (2-6)
Anxiety and insomnia subscale	3 (0-6)
Social dysfunction subscale	7 (6-7)
Severe depression subscale	0 (0-2)
GHQ total score	14 (10-20)
GHQ-28 case (GHQ-28 total ≥ 24, n %)	140 (18.6)
BSI	
Somatisation subscale	1 (0-4)
Obsessive-compulsive subscale	2 (0-3)
Interpersonal sensitivity subscale	2 (0-4)
Depression subscale	0 (0-2)
Anxiety subscale	1 (0-3)
Hostility subscale	1 (0-3)
Phobic anxiety subscale	2 (0-4)
Paranoid ideation subscale	3 (0-6)
Psychoticism subscale	2 (0-4)
BSI total score	18 (7-32)
BSI case ($T_{GSI} \geq T_{63,}$ n %)	169 (22.5)
BIS-11	
Attention impulsiveness subscale	16 (14-18)
Motor impulsiveness subscale	17 (15-21)
Non-planning subscale	20 (17-24)
BIS-11 total score	54 (46-61.5)
BIS-11 case (BIS-total ≥ 54, n %)	381 (50.7)
SSI	
Total suicidal ideation score	1 (0-2)
SSI case (SSI total ≥ 1, n %)	380 (50.5)

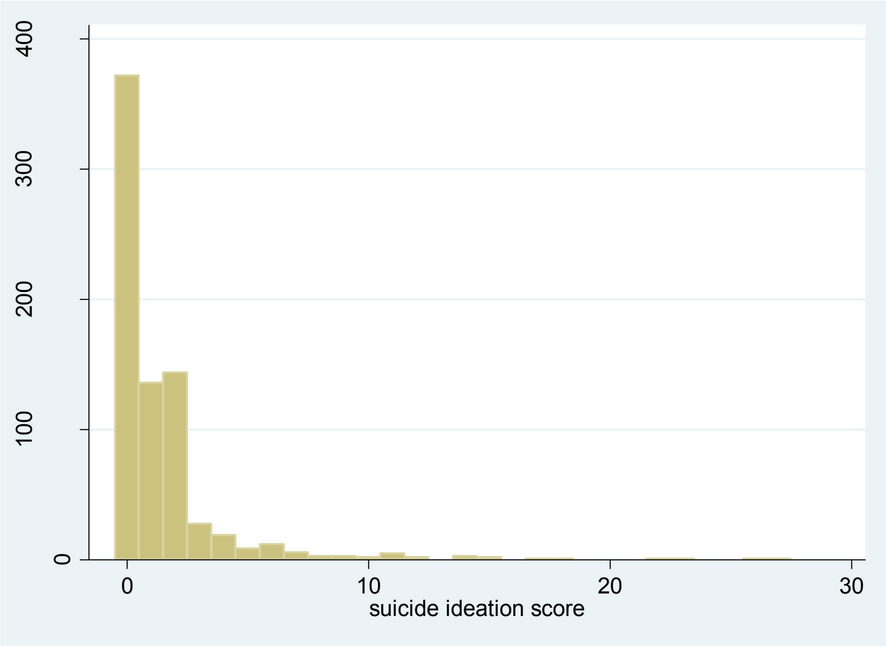

Figure 4.1 Histogram of the SSI questionnaire

Figure 4.2 displays the histograms of the depression subscales of the GHQ-28 and the BSI. The histograms for the depression subscales of both instruments revealed a skewed distribution with a large proportion of zero counts i.e. 408 (54.3%) on the GHQ-28 and 381 (50.7%) on the BSI. This effectively resulted in a limited range of values for the subscale with reduced discriminative power. For this reason, the four subscales of the GHQ-28 questionnaire and the nine subscales of the BSI questionnaire were used initially as a proxy measurement of depression in the SEM analysis.

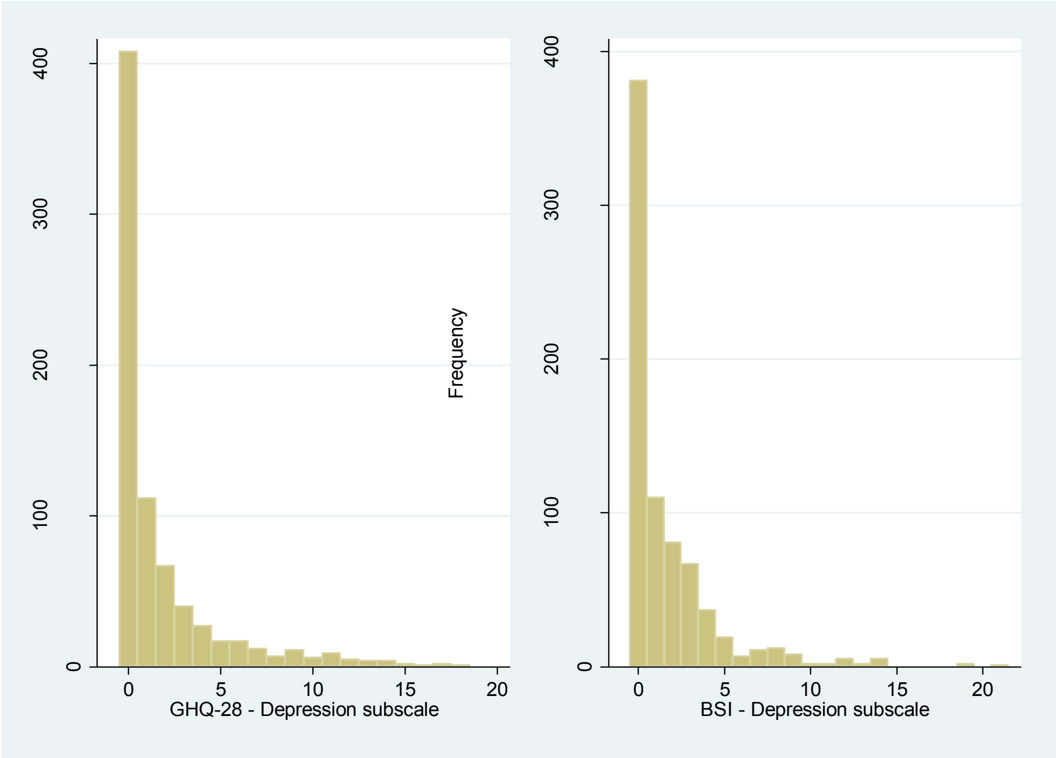

Figure 4.2 Histograms of the depression subscales of the GHQ-28 and BSI questionnaires

4.2.4 Potential confounders

One hundred and seven (14.2%) participants reported experiencing a past episode of OP pesticide poisoning. Of these respondents, 86 (80.3%) sought medical care from a doctor, of which 36 (41.9%) respondents were subsequently admitted to hospital.

56.4% (424) of the study participants admitted to current use of alcohol, with 248 (76.5%) of the remaining participants admitted to having used alcohol in the past. Of the current alcohol drinkers, 69.8% (296) constituted of males and 30.2% (128) were females. Of the 647 participants who completed the CAGE score questionnaire i.e. a screening tool for alcohol-related problems, a large proportion of participants (571, 88.3%) were categorised as having alcohol-related problems.

As the OP exposure profile was different for males and females, gender was viewed as a confounder. Table 4.6 summarises the above variables by gender.

Table 4.6 Descriptive profile of study sample by gender (n=752)

Variables	**Females**	**Males**	***p*-value**
Population (n, %)	305 (40.6)	447 (59.4)	
Age (median, IQR)	32 (27 - 39)	35 (28 - 44)	0.001 [a]
Socio-economic score			
Lower (n, %)	104 (34.1)	175 (39.2)	
Higher (n, %)	201 (65.9)	272 (60.8)	0.159 [b]
CAGE score			
n	242	405	
≥ 2 (n, %)	220 (38.5)	351 (61.5)	
< 2 (n, %)	22 (28.9)	54 (71.1)	0.105 [b]
History of past pesticide poisoning			
Yes (n, %)	37 (34.6)	70 (65.4)	
No (n, %)	268 (41.6)	377 (58.4)	0.174 [b]
Measures of psychological distress			
GHQ-28 total score (med, IQR)	15 (11 - 21)	13 (9 - 19)	0.002 [a]
GHQ-28 case (GHQ-28 total ≥ 24, n %)	66 (19.3)	74 (16.6)	
BSI total score (med, IQR)	20 (10 - 36)	16 (5 - 28)	0.001 [a]
BSI case ($T_{GSI} \geq T_{63}$, n %)	67 (21.9)	102 (22.8)	
Measures of depressive symptoms			
Severe depression subscale (med, IQR)	1 (0-3)	0 (0-2)	0.001 [b]
Depression subscale (med, IQR)	1 (0-3)	0 (0-2)	0.007 [b]
Measures of impulsive behaviour			
BIS-11 total score (med, IQR)	54 (46 - 62)	53 (46 - 61)	0.562 [a]
BIS-11 case (BIS-total ≥ 54, n %)	158 (41.5)	223 (58.5)	0.606 [b]
Measures of suicidal ideation			
SSI total score (med, IQR)	1 (0 - 2)	0 (0 - 2)	0.030 [a]
SSI case (SSI total ≥ 1, n %)	173 (56.7)	207 (46.3)	0.005 [b]

a - Pearson chi-squared p-value, b - Wilcoxon rank-sum (Mann-Whitney) p-value

Male farm workers were significantly older than female farm workers (35 vs. 32 years, p = 0.001). With regard to psychological distress, depression and suicidal ideation, female farm workers reported:

- Higher median levels of psychological distress on both the GHQ-28 (15 [IQR 11-21] vs. 13 [IQR 9-19], p=0.002) and the BSI questionnaire (20 [IQR 10 – 36] vs. 16 IQR [5 – 28], p = 0.001) than male farm workers.

- Higher median levels of depression on the GHQ-28 (1 [IQR 0 – 3] vs. 0 IQR [0-2], p = 0.001) and the BSI questionnaire (1 [IQR 0 – 3] vs. 0 IQR [0-2], p = 0.007).

- Higher median levels of suicidal ideation on the SSI (1 [IQR 0 – 2] vs. 0 IQR [0-2], p = 0.03) than male farm workers. In addition, a higher proportion of female farm workers had positive suicidal ideation score (56.7% vs. 46.3%, p = 0.005) compared to male farm workers.

4.3 Bivariate analysis

In this section, bivariate analysis of the exposure, outcome and confounding variables are summarised in tables and / or box-plots. Statistical significance was not reported for all bivariate associations as it would reflect a very large false discovery rate due to multiple testing. For example, 36 comparisons were conducted when testing the association between the nine OP exposure variables and the four subscales of the GHQ-28 (see table 4.7) and 81 comparisons when testing the association between the nine OP exposure variables and the nine subscales of the BSI (see table 4.8). Bearing this in mind, the percentage of associations significant at an unadjusted 5% level of significance was reported, to give an idea of the comparative strength of the OP exposure indicators with the subscales of the different instruments.

4.3.1 Association between OP pesticide exposure and outcomes

4.3.1.1 Correlation between psychological distress and various assessment of pesticide exposure

Table 4.7 summarises the Spearman's rank correlation coefficients of OP pesticide exposure variables and the four GHQ-28 subscales. The percentage of significant associations between OP exposure and the GHQ subscales were 11%. All correlations were small reflecting weak associations. Cumulative exposure was positively associated with three of the four symptoms but negatively (though not significantly) with the severe depression subscale.

Table 4.7 Spearman correlation between OP pesticide exposure variables and GHQ-28 subscales (n=752)

OP exposure variables (years)	GHQ-A	GHQ-B	GHQ-C	GHQ-D
Spraying from the back of a tractor	-0.065	-0.029	-0.018	-0.100
Hand spraying pesticides	0.050	0.013	0.024	0.022
Spraying pesticides using a backpack	-0.018	0.028	0.036	-0.020
Maintenance work	0.013	0.006	0.066	-0.009
Gardening	-0.017	0.052	-0.039	0.025
Harvesting	0.013	0.027	0.034	0.014
Dipping livestock	-0.032	-0.023	-0.035	0.009
Orchards	0.032	0.052	0.027	0.033
Cumulative years exposed	0.081	0.076	0.075	-0.035

GHQ-A: somatic symptoms, GHQ-B: anxiety and insomnia, GHQ-C: social dysfunction, GHQ-D: severe depression.

Table 4.8 summarises the Spearman rank correlation coefficients of OP pesticide exposure and nine BSI subscales. The percentage of significant associations between OP exposure and the BSI subscales were 33%. There were slightly stronger associations between OP exposure and certain subscales, notably BSI-I (psychotism subscale), but mostly negative.

Table 4.8 Spearman correlation between OP pesticide exposure variables and BSI subscales (n=752)

OP exposure variables (years)	BSI-A	BSI-B	BSI-C	BSI-D	BSI-E	BSI-F	BSI-G	BSI-H	BSI-I
Spraying from the back of a tractor	-0.031	-0.088	-0.115	-0.100	-0.073	-0.019	-0.161	-0.095	-0.117
Hand spraying pesticides	0.023	-0.019	-0.040	-0.002	-0.051	0.007	-0.079	-0.052	-0.107
Spraying pesticides using a backpack	-0.006	-0.039	-0.077	0.016	-0.007	0.018	-0.096	-0.075	-0.095
Maintenance work	-0.003	0.023	-0.062	-0.042	-0.033	-0.076	-0.073	-0.064	-0.098
Gardening	0.039	0.038	0.032	-0.067	0.009	0.096	-0.035	0.073	0.072
Harvesting	0.007	0.003	-0.074	-0.043	-0.048	-0.057	-0.009	-0.065	-0.119
Dipping livestock	0.025	0.013	-0.006	-0.006	0.009	0.042	-0.049	-0.009	-0.062
Orchards	0.026	-0.007	-0.103	-0.056	-0.022	-0.124	-0.124	-0.088	-0.130
Cumulative years exposed	0.088	0.064	-0.070	-0.025	0.015	-0.059	-0.059	-0.059	-0.069

BSI-A: somatisation, BSI-B: obsessive-compulsive, BSI-C: interpersonal sensitivity, BSI-D: depression: BSI-E: anxiety, BSI-F: hostility, BSI-G: phobic anxiety, BSI-H: paranoid ideation, BSI-I: psychotism

4.3.1.2 Correlation between Impulsive behaviour and various assessment of pesticide exposure

Table 4.9 summarises the Spearman rank correlation coefficients of OP pesticide exposure variables and three BIS-11 subscales. The percentage of significant associations between OP exposure and the BIS-11 subscales were 63%. As shown with symptoms of psychological distress, the correlations were small reflecting weak relationships. There were slightly stronger associations between OP exposure and the BIS-C subscale (non-planning impulsiveness), though mostly negative.

Table 4.9 Spearman correlation between OP pesticide exposure variables and BIS-11 subscales (n=752)

OP exposure variables	BIS-A	BIS-B	BIS-C
Spraying from the back of a tractor	0.000	-0.065	-0.090
Hand spraying pesticides	-0.090	-0.085	-0.110
Spraying pesticides using a backpack	-0.053	-0.028	-0.051
Maintenance work	-0.159	-0.095	-0.152
Gardening	0.052	0.058	0.082
Harvesting	-0.160	-0.079	-0.146
Dipping livestock	0.015	-0.004	-0.006
Orchards	-0.082	-0.096	-0.120
Cumulative years exposed	-0.142	-0.110	-0.141

BIS-A: cognitive impulsiveness, BIS-B: motor impulsiveness, BIS-C: non-planning impulsiveness

4.3.1.3 Correlation between Suicidal ideation and various assessment of pesticide exposure

Table 4.10 summarises the Spearman rank correlation coefficients of OP pesticide exposure variables and the total suicidal ideation score. The percentage of significant associations between OP exposure variables and the total suicide score was 70%. All associations between the exposure occupations and suicidal ideation were negative. The predominant exposure occupations that reflected stronger associations with suicidal ideation were spraying from the back of a tractor, hand spraying pesticides and harvesting.

Table 4.10 Spearman correlation between OP pesticide exposure variables and SSI total score (n=752)

OP exposure variables	Spearman rho
Spraying from the back of a tractor	-0.130
Hand spraying pesticides	-0.130
Spraying pesticides using a backpack	-0.076
Maintenance work	-0.113
Gardening	-0.013
Harvesting	-0.135
Dipping livestock	-0.012
Orchards	-0.111
Cumulative years exposed	-0.118

4.3.2 Relationship between depression, impulsive behaviour and suicidal ideation

4.3.2.1 Association between the GHQ-28 and BSI questionnaire

Male farm workers categorised as having psychological distress were 102 (22.8%) as scored by the BSI (cut-off score ≥ T_{63}; Derogatis, 1993) and 74 (16.6%) as scored by GHQ-28 (cut-off score ≥ 24; Goldberg, 1997). Female farm workers categorised as having psychological distress were 67 (21.9%) as scored by the BSI (cut-off score ≥ T_{63}; Derogatis, 1993) and 59 (19.3%) as scored by GHQ-28 (cut-off score ≥ 24; Goldberg, 1997). The agreement between the GHQ-28 and the BSI is summarised in table 4.11.

Table 4.11 Agreement between the GHQ-28 and the BSI questionnaires by gender

Variable	BSI	GHQ-28	Agreement, in %	Kappa	Standard error	p-value
Psychological distress in males (n, %)	102 (22.8)	74 (16.6)	91.2	0.56	0.035	<0.001
Psychological distress in females (n, %)	67 (21.9)	59 (19.3)	92.3	0.50	0.036	<0.001

For the male farm workers, the agreement between the two instruments was "moderate" (kappa = 0.56, se = 0.035, z = 15.83, p < 0.001) i.e. 56% of the difference between perfect agreement and expected by chance was accounted for by the agreement between the GHQ-28 and BSI questionnaires for male farm workers.

The agreement between the two questionnaires was also "moderate" (kappa= 0.50, se = 0.036, z = 13.68, p < 0.001) i.e. 50% of the difference between perfect agreement and the agreement expected by chance was accounted for by the agreement between the GHQ-28 and BSI questionnaires for female farm workers.

In addition, there was a positive correlation between the depression subscales of the GHQ-28 and BSI (Spearman rho=0.452, p<0.001).

4.3.2.2 Depressive symptoms, symptoms of psychological distress and suicidal ideation

There was a significant positive association between total suicidal ideation score and both the GHQ-28 total score (Spearman rho=0.171, p<0.001) and all its sub-scales, including:

- somatisation (Spearman rho=0.079, p=0.03),
- anxiety and insomnia (Spearman rho=0.154, p<0.001),
- social dysfunction (Spearman rho = 0.085, p = 0.02),
- severe depression (Spearman rho=0.191, p<0.001).

Similarly for the BSI questionnaire, there was a significant positive association between the total suicidal ideation score and both the BSI total score (Spearman rho=0.393, p<0.001) and all its sub-scales, including:

- somatisation (Spearman rho=0.183, p<0.001),
- obsessive-compulsive (Spearman rho=0.297, p<0.001),
- interpersonal sensitivity (Spearman rho=0.322, p<0.001),
- depression (Spearman rho=0.222, p<0.001),
- anxiety (Spearman rho=0.188, p<0.001),
- hostility (Spearman rho=0.177, p<0.001),
- phobic anxiety (Spearman rho=0.340, p<0.001),
- paranoid ideation (Spearman rho=0.408, p<0.001), and
- psychotism (Spearman rho=0.421, p<0.001).

4.3.2.3 Impulsive behaviour and suicidal ideation

There was a significant positive association between total suicidal ideation score and the BIS-11 total score (Spearman rho=0.414, p<0.001), and all its subscales: attention impulsiveness (Spearman rho=0.204, p<0.001), motor impulsiveness (Spearman rho=0.400, p<0.001) and the non-planning impulsiveness (Spearman rho= 0.333, p<0.001).

4.3.2.4 Depressive symptoms, symptoms of psychological distress and impulsive behaviour

There was a significant positive association between the severe depression subscale of the GHQ-28 and total BIS score (Spearman rho=0.215, $p<0.001$). Similarly, there was a significant positive association between the depression subscale of the BSI and total BIS score (Spearman rho=0.291, $p<0.001$). With regard to psychological distress, the total GHQ-28 score was significantly and positively associated with the total BIS score (Spearman rho= 0.160, $p<0.001$). Similarly, the total BSI score was significantly and positively associated with total BIS score (Spearman rho=0.429, $p<0.001$).

In general, these results indicate positive relationships between these constructs and hence bode well for the endogenous paths of the SEM models.

4.3.3 Relationship between potential confounders, OP exposure and outcomes

The following potential confounding variables were examined by bivariate analysis for relationships with OP exposure variables and outcome variables: age of the farm worker, gender, history of past OP pesticide poisoning, socioeconomic score and the CAGE score.

4.3.3.1 Age

a) Age and exposure

There was a strong positive correlation between age and the cumulative years worked in agriculture (Spearman rho=0.742, $p<0.001$). Age was also positively correlated with the individual OP exposure activities (range: Spearman rho=0.098-0.486).

b) Age and outcomes

There was no association between age and the depression subscales of the GHQ-28 and BSI questionnaire. However, there was a significant positive (but weak) correlation between age and somatic symptoms subscale of the GHQ-28 questionnaire (Spearman rho=0.095, $p=0.009$). In addition, there was a significant positive correlation between age and the BSI somatisation subscale (Spearman rho=0.138, $p=0.001$) and the BSI obsessive-compulsive subscale (Spearman rho=0.089, $p=0.01$). In other words, as farm workers got older, their somatisation and obsessive-compulsive scores increased.

Age of the farm worker was significantly and negatively associated with the attention impulsiveness subscale (Spearman rho=-0.108, $p=0.003$) and non-planning subscale of the BIS-11 (Spearman rho=-0.113, $p=0.002$). In other words, older farm workers were less impulsive on the attention and non-planning subscales. There was no significant association between age of the farm worker and total suicidal ideation score (Spearman rho=-0.040, p=0.276). As shown in table 4.6, male farm workers were significantly older than female farm workers (35 vs. 32 years, p = 0.001).

4.3.3.2 Gender

a) Gender and exposure

Tables 4.2 to 4.4 (pages 58 & 59) compared the exposure variables by gender. Male farm workers had a distinctively different OP pesticide exposure profile from female farm workers in both the nature of the pesticide applicator activities as well as the median duration of years exposed to the pesticides as discussed in section 4.2.2 (page 57).

b) Gender and outcomes

Figure 4.3 displays the box-and-whisker plots of the mental health outcomes by gender.

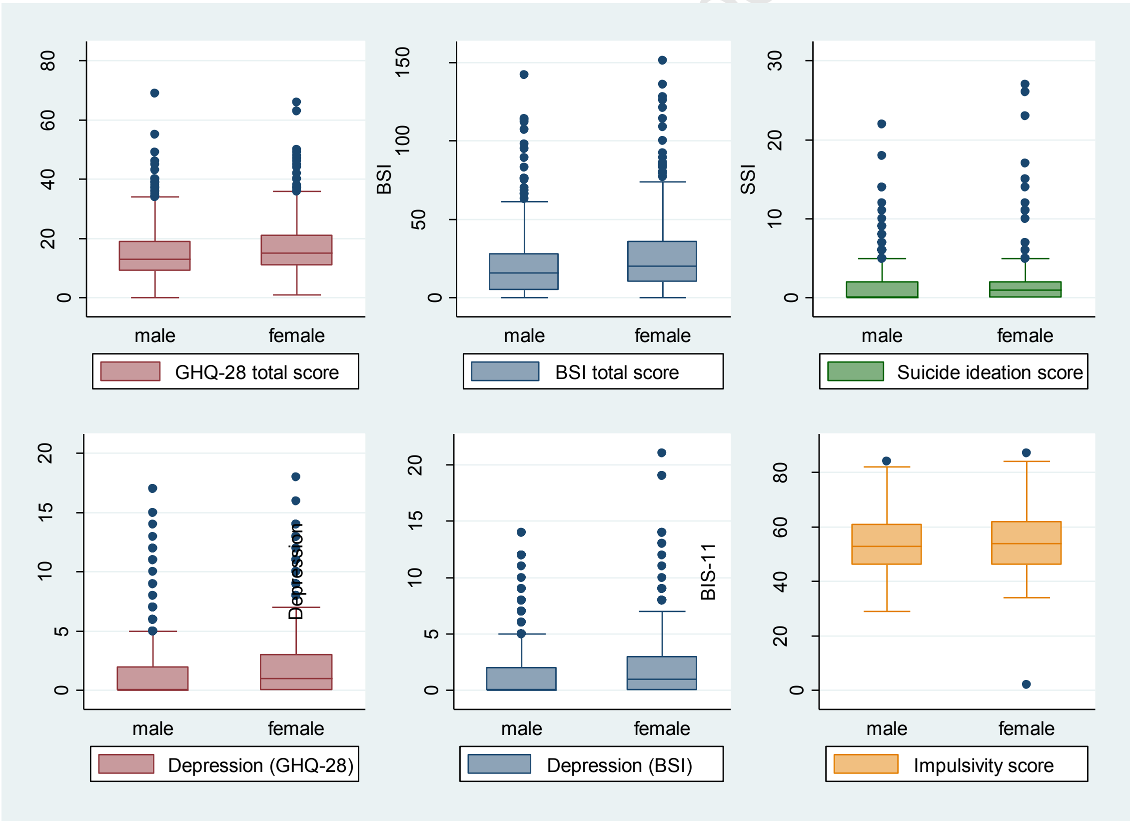

Figure 4.3 Box-and-whisker plots of mental health outcomes by gender

Summarised in section 4.2.4 (page 62), female farm workers reported higher levels of psychological distress, depression and suicidal ideation than male farm workers. There was no gender difference in the level impulsive behaviour reported by farm workers.

4.3.3.3 History of past OP pesticide poisoning

a) History of past OP pesticide poisoning and exposure

Of the 752 respondents, 107 (14.2%) study participants reported a history of past pesticide poisoning. Table 4.12 compares the median time exposed to OP pesticides through various farming / pesticide applicator activities and a history of previous pesticide poisoning.

Table 4.12 Summary of OP pesticide exposure by history of past poisoning (n=752)

OP exposure variable (measured in years)	History of past poisoning	No past history
	median (IQR)	median (IQR)
Population (n, %)	107 (14.2)	645 (85.8)
Spraying from the back of a tractor	0 (0-3)	0 (0-0)
Hand spraying pesticides	2 (0-8)	0 (0-7)
Spraying pesticides using a backpack	0 (0-6)	0 (0-1)
Maintenance work	9 (5-16)	7 (3-14)
Gardening	0 (0-6)	0 (0-4)
Harvesting	8 (4-16)	7 (2-14)
Dipping livestock	0 (0-0)	0 (0-0)
Orchards	7 (3-15)	4 (0-11)
Cumulative years exposed	15 (7-22)	11 (5-19)

Farm workers with a history of past poisoning were cumulatively exposed to pesticides over a longer period than those with no past history. Similarly farm workers with a history of past poisoning were exposed to pesticides over longer periods in the following pesticide applicator activities: hand spraying pesticides, maintenance work, harvesting and orchard work.

In the male subsample, farm workers with a history of past poisoning were cumulatively exposed to OP pesticides over a longer period than those with no past history (16.5 years [IQR 8.5-22 years] vs. 12 years [5-22.4 years]). Male farm workers with a history of past poisoning were exposed over longer periods of time in the following exposure activities: hand spraying, maintenance work, harvesting and working in an orchard.

In the female subsample, farm workers with a history of past poisoning were cumulatively exposed to OP pesticides over a slightly longer period than those with no past history (11 years [IQR 6-21.8 years] vs. 10 [5-17years]). Similarly female farm workers with a history of past poisoning were exposed to pesticides over longer periods in the following pesticide applicator activities: maintenance work, harvesting and working in an orchard.

b) History of past OP pesticide poisoning and outcomes

Table 4.13 compares farm workers with mental health outcomes by a history of past OP pesticide poisoning. The percentage of significant associations between mental health outcomes and history of past pesticide poisoning was 40%. No difference was found between the median impulsivity, depression (by both GHQ-28 and BSI) and suicidal ideation scores in farm workers with a history of past pesticide poisoning compared to farm workers with no past history.

However, farm workers with a history of past poisoning reported increased *levels* of psychological distress and increased *symptoms* of psychological distress than farm workers with no past history i.e. the subscales and total scores of the GHQ-28 and the BSI questionnaire.

In the male subsample, farm workers with a history of past poisoning reported increased median *levels* of psychological distress (15 [12-22] vs. 13 [9-19]) as measured by the GHQ-28 questionnaire and increased *symptoms* of somatisation and anxiety than those with no past history of poisoning. Similarly male farm workers with a history of past poisoning reported increased median levels of psychological distress (18.5 (IQR 8-34] vs. 16 [IQR 5-28]) as measured by the BSI questionnaire. In addition, male farm workers reported increased symptoms of somatisation, obsession-compulsive behaviour, depression and phobic anxiety. There was no difference in the levels of impulsivity and suicidal ideation between the two groups.

Similarly, female farm workers with a history of past poisoning reported increased median *levels* of psychological distress (19 [12-28] vs. 15 [11-21]) as measured by the GHQ-28 questionnaire and increased symptoms of anxiety than those with no past history of poisoning. With regard to the BSI questionnaire, female farm workers with a history of past poisoning reported elevated median *levels* of psychological distress (28 [16-51] vs. 20 [9.5-34]) compared to those with no past history as well as increased symptoms of somatisation, obsessive-compulsive behaviour, depression and paranoid ideation. As with the male farm workers, there was no difference in the levels of impulsivity and suicidal ideation between the two groups.

Table 4.13 Summary of median outcome scores by past history of OP pesticide poisoning (n=752)

Instrument scores	**Past history of poisoning**	**No past history**
	Median (IQR)	**Median (IQR)**
Population (n, %)	107 (14.2)	645 (85.8)
GHQ-28		
Somatic symptoms subscale	5 (3-7)	3 (2-6)
Anxiety and insomnia subscale	4 (1-7)	3 (0-5)
Social dysfunction subscale	7 (6-7)	7 (6-7)
Severe depression subscale	0 (0-3)	0 (0-2)
GHQ total score	15 (12-24)	14 (10-20)
BSI		
Somatisation subscale	3 (1-6)	1 (0-4)
Obsessive-compulsive subscale	2 (0-6)	1 (0-3)
Interpersonal sensitivity subscale	2 (0-4)	2 (0-4)
Depression subscale	1 (0-3)	0 (0-3)
Anxiety subscale	2 (0-5)	1 (0-3)
Hostility subscale	1 (0-3)	1 (0-3)
Phobic anxiety subscale	2 (0-5)	1 (0-4)
Paranoid ideation subscale	3 (1-7)	3 (0-6)
Psychoticism subscale	2 (0-4)	2 (0-4)
BSI total score	20 (9-42)	18 (7-30)
BIS-11		
Attention impulsiveness subscale	15 (12-18)	16 (14-18)
Motor impulsiveness subscale	16 (14-21)	17 (15-21)
Non-planning subscale	20 (17-23)	20 (17-24)
BIS-11 total score	52 (45-61)	54 (47-62)
SSI		
Total suicidal ideation score	0 (0-2)	1 (0-2)

4.3.3.4 Socioeconomic score

a) Socioeconomic score and exposure

In the study sample, 279 (37.1%) participants were categorised as having low socioeconomic score. Table 4.14 summarised the exposure variables (median and IQR) by socioeconomic score. The percentage of significant associations between socioeconomic score and exposure activities were 55%. Overall, respondents with a *high* socioeconomic score were associated with longer duration of exposure cumulatively and in the following farming / pesticide applicator tasks: maintenance work, harvesting and orchard work.

Table 4.14 Summary of exposure variables by socioeconomic status (n=752)

OP exposure variable (measured in years)	Low SES	High SES
	median (IQR)	median (IQR)
Population (n, %)	279 (37.1)	473 (62.9)
Spraying from the back of a tractor	0 (0-0)	0 (0-0)
Hand spraying pesticides	2 (0-7)	0 (0-7)
Spraying pesticides using a backpack	0 (0-3)	0 (0-1)
Maintenance work	6 (2-11)	8 (3-16)
Gardening	0 (0-5)	0 (0-4)
Harvesting	5 (2-11)	8 (3-16)
Dipping livestock	0 (0-0)	0 (0-0)
Orchards	4 (0.5-11)	5 (0-12)
Cumulative years exposed	10 (5-18.3)	13 (6-21)

By gender, male farm workers categorised with a *high* socioeconomic score were associated with longer duration of OP exposure cumulatively [14.5 years [IQR 7-24 years] vs. 10 years [IQR 5-19 years] and in the following farming / pesticide applicator tasks: hand spraying, maintenance work and harvesting.

Similarly, female farm workers categorised with a *high* socioeconomic score were associated with longer duration of OP exposure cumulatively [11 years [IQR 5-17 years] vs. 9 years [IQR 5-16.5 years] and in the following farming / pesticide applicator tasks: maintenance work and harvesting.

b) Socioeconomic score and outcomes

Figure 4.4 displays the box-and-whisker plots of the mental health outcomes by socioeconomic score. The percentage of significant associations between socioeconomic score and mental health outcomes were 50%. Farm workers with *low* socioeconomic score reported elevated levels of psychological distress than those with high socioeconomic score for both the GHQ-28 (15 [IQR 11-22] versus 14 [IQR 10-20]) and BSI questionnaire (20 [IQR 9-39] versus 17 [IQR 6-28]). Similarly, farm workers with *low* socioeconomic score reported elevated levels of depression than those with high socioeconomic score for both the GHQ-28 (1 [IQR 0-3] versus 0 [IQR 0-2]) and BSI (1 [IQR 0-3] versus 0 [IQR 0-2]). In addition, farm workers with *low* socioeconomic score reported elevated levels of impulsivity than those with high socioeconomic score (57 [IQR 47-54] versus 53 [46-60]).

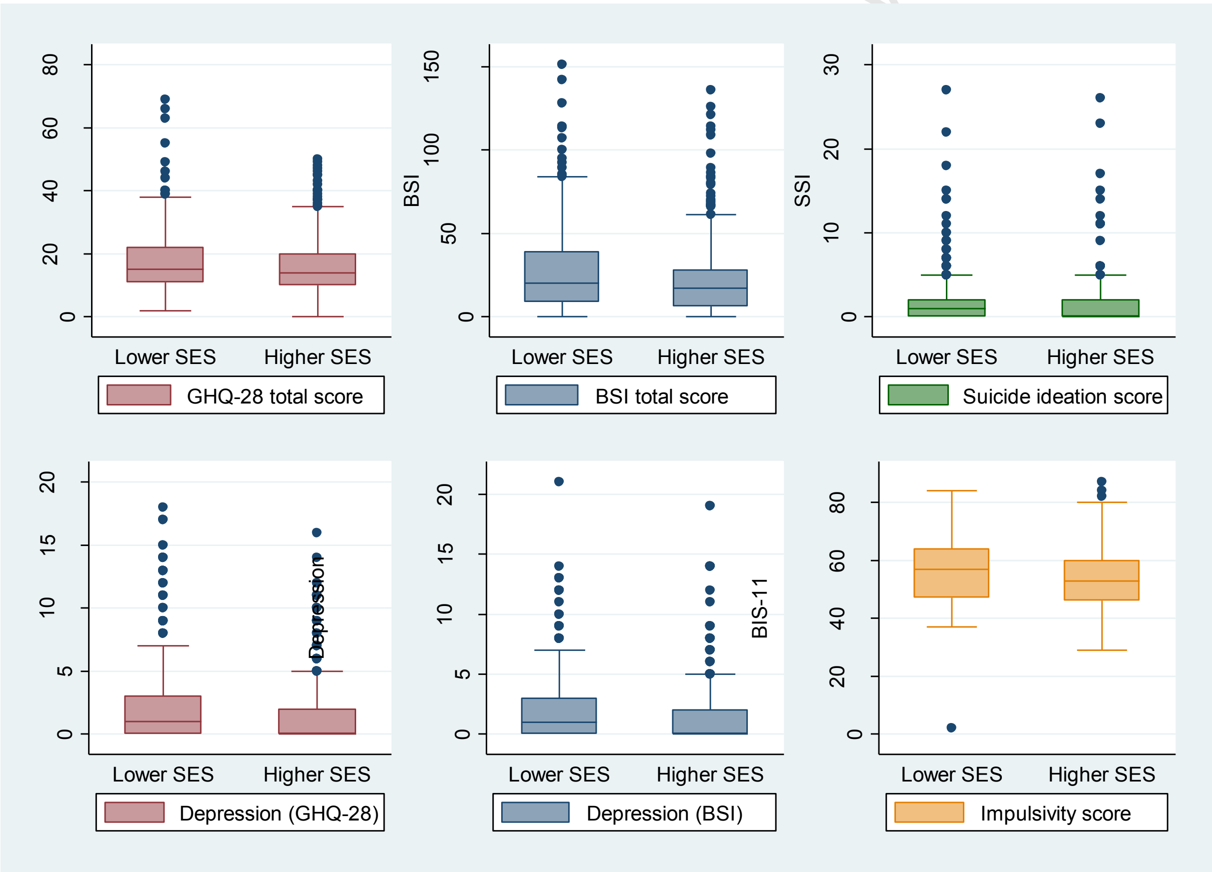

Figure 4.4 Box-and-whisker plots of mental health outcomes by SES

In the male subsample, there was a slight difference in the levels of psychological symptoms reported as measured by the GHQ-28 questionnaire in the two groups (14 [IQR 10-21] vs. 13 [IQR [9-19] with increased levels of severe depression reported in the low socioeconomic group. Higher levels of psychological distress was reported in male farm workers categorised by a low socioeconomic score as measured by the BSI (20 [IQR 7-34] vs. 15.5 [IQR 5-27]). In addition, farm workers with *low* socioeconomic score reported elevated levels of impulsivity than those with higher socioeconomic score (57 [IQR 47-64] versus 52 [45-60]).

Similarly, female farm workers categorised by a lower socioeconomic score reported slightly elevated levels of psychological distress (16 [IQR 11.5-23] vs. 15 [IQR [11-21] as measured with the GHQ-28. There was no difference in levels of psychological distress reported by the two groups as measured by the BSI. Female farm workers with a low socioeconomic score reported higher levels of impulsive behaviour than those with a higher socioeconomic score (57 [IQR 45.5-63] versus 53 [47-60]).

Overall, farm workers with a *low* socioeconomic score reported elevated median levels of psychological distress, depression and impulsivity. There was no difference in the levels of suicidal ideation reported in the two groups.

4.3.3.5 CAGE score

a) CAGE score and exposure

Table 4.15 compared exposure variables by CAGE score reported by farm workers. A positive CAGE score was indicated by a value greater than and equal to 2. The percentage of significant associations between exposure activities and CAGE score was 56%. Overall, a positive CAGE score was associated with a longer duration exposure cumulatively and in the following farming / pesticide applicator activities: hand spraying pesticides, maintenance work, harvesting and orchard work.

In the male subsample, a positive CAGE score was associated with longer duration of exposure cumulatively (14 years [IQR 7-23 years] vs. 9 years [IQR 2.2-14 years] and in the following farming / pesticide applicator activities: hand spraying pesticides, maintenance work, harvesting and orchard work.

In the female subsample, a positive CAGE score was associated with longer duration of exposure cumulatively (10 years [IQR 6-17] vs. 7 years [IQR 2-11 years] and in the following farming / pesticide applicator activities: maintenance work, harvesting and orchard work.

Table 4.15 Summary of exposure by CAGE score (n=647)

OP exposure variable (measured in years)	CAGE<2	CAGE≥2
	median (IQR)	median (IQR)
Population (n, %)	76 (11.75)	571 (88.25)
Spraying from the back of a tractor	0 (0-0)	0 (0-0)
Hand spraying pesticides	0 (0-4)	2 (0-9)
Spraying pesticides using a backpack	0 (0-2.5)	0 (0-3)
Maintenance work	5 (1.5-10)	8 (3-16)
Gardening	0 (0-5)	0 (0-5)
Harvesting	5 (1-10.5)	7 (3-16)
Dipping livestock	0 (0-0)	0 (0-0)
Orchards	2.5 (0.15-9)	5 (0.3-12)
Total years worked in agricultural sector	8 (2.1-13)	13 (6-21)

b) Alcohol and outcomes

Table 4.16 compared the median scores of the questionnaires by CAGE score. The percentage of significant associations between exposure activities and CAGE score was 15%. Farm workers with a positive CAGE score reported higher levels of somatisation symptoms for both GHQ-28 and BSI. There was no difference in the levels of impulsivity and suicidal ideation reported by farm workers when compared by a positive CAGE score.

Male farm workers categorised with a positive CAGE score reported elevated levels of psychological distress as measured by the BSI questionnaire (19 [IQR 7-31] vs. 10.5 [IQR 2-24]. There was no difference in the levels of impulsivity and suicidal ideation reported by male farm workers when compared by a positive CAGE score.

In the female subsample, there was no difference in the levels of psychological distress, depression, impulsivity and suicidal ideation reported in female farm workers categorised by the CAGE score.

Table 4.16 Summary of median outcome measures by CAGE score (n=647)

Instrument scores	CAGE<2 median (IQR)	CAGE≥2 median (IQR)
Population (n, %)	76 (11.75)	571 (88.25)
GHQ-28		
Somatic symptoms subscale	3 (1-5)	4 (2-6)
Anxiety and insomnia subscale	2.5 (0-5)	3 (0-6)
Social dysfunction subscale	7 (6-7)	7 (6-7)
Severe depression subscale	0 (0-2.5)	0 (0-2)
GHQ total score	14 (9-19)	14 (10-21)
BSI		
Somatisation subscale	1 (0-3)	2 (0-5)
Obsessive-compulsive subscale	1 (0-3)	2 (0-4)
Interpersonal sensitivity subscale	1 (0-3)	2 (0-4)
Depression subscale	0 (0-2)	1 (0-3)
Anxiety subscale	1 (0-2)	1 (0-4)
Hostility subscale	1 (0-3)	1 (0-3)
Phobic anxiety subscale	1 (0-3)	2 (0-4)
Paranoid ideation subscale	2.5 (0-5)	3 (1-6)
Psychoticism subscale	1 (0-3)	2 (0-4)
BSI total score	12.5 (5-31.5)	20 (9-34)
BIS-11		
Attention impulsiveness subscale	15 (13-17.5)	16 (14-18)
Motor impulsiveness subscale	18.5 (16-22)	17 (15-21)
Non-planning subscale	20 (16.5-24.5)	20 (17-24)
BIS-11 total score	53.5 (45-62)	55 (47-62)
SSI		
Log total suicide score	1 (0-2)	1 (0-2)

4.3.4 Summary of univariate and bivariate analysis

In the study sample, the proportion of the respondents categorised as having of psychological distress based on the two instruments were: 18.6% of participants on the GHQ-28 (cut-off score ≥ 24) and 22.5% of participants based on the standard t-scores of the global severity index (T_{GSI}) of the BSI (cut-off score ≥ T_{63}). Use of the median as a cut-off categorized 50.7% of the respondents as having impulsive behaviour based on the BIS-11 (median cut-off score ≥ 54) and 50.5% of the respondents as having suicidal ideation (median cut-off score ≥ 1). When comparing the mental health outcomes by gender, female farm workers reported higher median levels of psychological distress, depression and suicidal ideation than male farm workers. There was a higher proportion of psychological distress in the female farm workers (19%) than male farm workers (17%). Similarly, the proportion of suicidal ideation in the female respondents (57%) was higher than in the male respondents (46%).

The predominant occupations leading to OP exposure were maintenance work, harvesting and working in the orchards for both males and female farm workers. In addition, most males were also exposed whilst hand spraying pesticides. The farm work / pesticide applicator activities were mostly negatively associated with symptoms of psychological distress including depression; impulsive behaviour and suicidal ideation. The correlations between exposure variables and mental health outcomes were small, implying weak associations. The agreement between the BSI and GHQ-28 measuring psychological distress was "moderate" for both male and female farm workers. Depressive symptoms and symptoms of psychological distress were positively associated with suicidal ideation. Impulsive behaviour was positively associated with suicidal ideation. Depressive symptoms and symptoms of psychological distress were positively associated with impulsive behaviour.

There was a strong correlation between age and cumulative OP exposure. However the correlations between age and mental health outcomes were small, again implying weak associations.

A history of past poisoning reported by farm workers was associated with longer duration spent in the following exposure activities: hand spraying pesticides, maintenance work, harvesting and orchard work. In addition, these farm workers reported increased levels of psychological distress and increased symptoms of psychological distress than farm workers with no past history. There was no difference in the level of depression, impulsivity and suicidal ideation reported in the two groups.

Farm workers with a *high* socioeconomic score were associated with longer duration of exposure cumulatively and in the following farming / pesticide applicator tasks: maintenance work, harvesting and orchard work. However, farm workers with a *low* socioeconomic score reported higher median levels of psychological distress, depression and impulsivity.

Farm workers reporting a positive CAGE score were associated with a longer duration of exposure cumulatively and in the following farming / pesticide applicator activities: hand spraying pesticides, maintenance work, harvesting and orchard work. These farm workers reported higher levels of somatisation symptoms for both GHQ-28 and BSI but not higher levels of depression, impulsivity or suicidal ideation.

4.4 Multivariate analysis

The following sections present the data derived from the male farm workers subsample (n=447). Female farm workers were removed from the multivariate analysis due to the differences in exposure profiles by gender and the development of identification and estimation problems (chapter three, section 3.4; page 54).

4.4.1 Factor analysis of the SSI

4.4.1.1 Correlation among the SSI items

Table 4.17 summarises the Spearman rank correlations of the 19 SSI items. Items SI17 (*suicide note*), SI18 (*final acts*) and SI19 (*deception or concealment*) had lower partial correlations and had a higher proportion of not significant partial correlations.

4.4.1.2 Assumptions in factor analysis

The sample size was a 24:1 ratio of observations to variables which falls within the acceptable limits i.e. more than 10:1 (Hair *et al,* 2010). An overall KMO measure of sampling adequacy of 0.78 was considered “middling” to continue factor analysis.

4.4.1.3 Deriving factors and assessing overall fit

The SSI score of 447 male subjects were subjected to principal component analysis with varimax and oblique rotation. Using the latent root criterion of retaining factors of eigenvalues > 1, six common factors were retained that accounted for 61.3% of the total variance. The scree test (figure 4.5) suggested that four factors may be appropriate when considering the changes in eigenvalues (i.e. identifying the elbow in the eigenvalues). However, in view of the original three factors reported by Beck *et al* (1979) i.e. “active suicidal desire”, “specific plans for suicide” and “passive suicide desire”, a priori criterion approach was used and three factors were retained. The 3 factors accounted for 43.9% of the total variance.

Table 4.17 Spearman rank correlation of 19 items of SSI (n=447)

	SI1	SI2	SI3	SI4	SI5	SI6	SI7	SI8	SI9	SI10	SI11	SI12	SI13	SI14	SI15	SI16	SI17	SI18	SI19
SI1	1.000																		
SI2	0.519	1.000																	
SI3	0.097	0.042	1.000																
SI4	0.422	0.449	-0.023	1.000															
SI5	0.271	0.195	0.054	0.293	1.000														
SI6	0.398	0.154	0.071	0.577	0.338	1.000													
SI7	0.143	0.281	-0.022	0.391	0.183	0.367	1.000												
SI8	0.235	0.133	0.149	0.522	0.244	0.593	0.559	1.000											
SI9	0.172	0.146	0.167	0.219	0.120	0.284	0.240	0.320	1.000										
SI10	0.303	0.378	0.192	0.345	0.246	0.322	0.277	0.530	0.572	1.000									
SI11	0.168	0.171	0.033	0.261	0.131	0.237	0.199	0.271	0.243	0.268	1.000								
SI12	0.324	0.306	-0.020	0.571	0.201	0.397	0.299	0.480	0.260	0.407	0.177	1.000							
SI13	0.106	0.133	0.057	0.199	0.066	0.079	0.327	0.346	0.105	0.215	0.236	0.359	1.000						
SI14	-0.019	0.046	0.217	0.085	0.008	0.073	0.203	0.155	0.448	0.278	0.218	0.225	0.246	1.000					
SI15	0.156	0.196	-0.020	0.425	0.207	0.259	0.300	0.481	0.453	0.518	0.225	0.658	0.233	0.344	1.000				
SI16	0.357	0.338	-0.018	0.466	0.227	0.439	0.159	0.393	0.291	0.332	0.205	0.725	0.255	0.116	0.541	1.000			
SI17	-0.006	-0.009	-0.008	-0.006	-0.013	-0.007	-0.006	0.293	0.219	0.258	0.092	0.403	0.296	0.289	0.402	0.444	1.000		
SI18	0.029	0.022	0.069	0.014	0.354	0.008	0.022	-0.002	0.079	0.021	0.037	0.029	0.043	-0.011	0.030	0.039	-0.016	1.000	
SI19	0.042	-0.029	0.084	0.019	0.192	0.051	0.030	0.068	0.178	0.067	0.007	0.041	0.104	0.233	0.090	0.056	0.097	0.020	1.000

Legend

- not significant
- $p < 0.05$
- $p < 0.01$
- $p < 0.001$

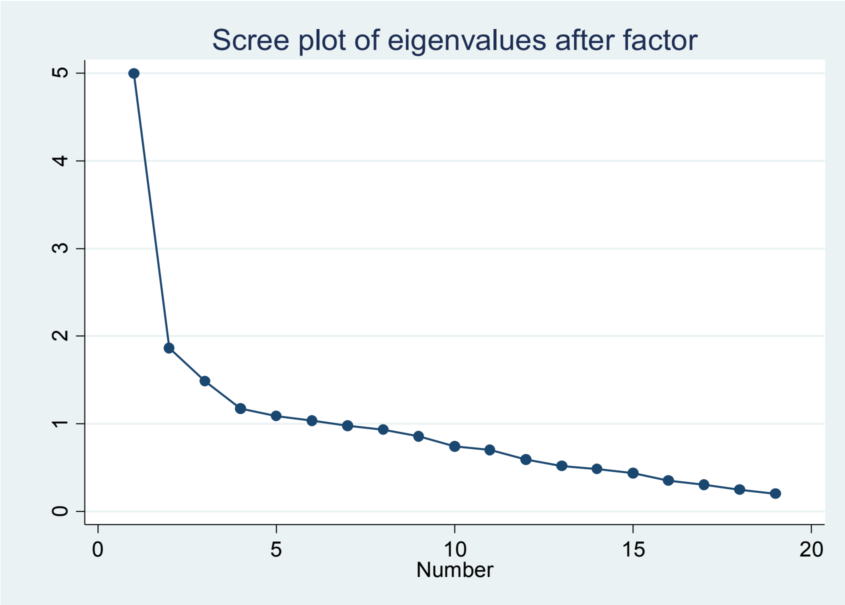

Figure 4.5 Scree plot of the eigenvalues

Table 4.18 Item-total Spearman rank correlation of the SSI (n=447)

Item	**Item-total score correlation**	**p-value**
Wish to live	0.207	<0.001
Wish to die	0.275	<0.001
Reason for living or dying	0.248	<0.001
Actual suicide desire	0.245	<0.001
Passive suicide desire	0.403	<0.001
Duration	0.250	<0.001
Frequency	0.227	<0.001
Attitude toward ideation	0.287	<0.001
Control over action	0.351	<0.001
Deterrents to attempt	0.328	<0.001
Reason for attempt	0.693	<0.001
Specificity of planning	0.203	<0.001
Availability and opportunity	0.265	<0.001
Capacity	0.282	<0.001
Expectancy	0.217	<0.001
Actual preparation	0.193	<0.001
Suicide note	0.089	0.351
Final acts	0.404	<0.001
Deception or concealment	0.413	<0.001

Spearman product-moment "item-total" correlations were computed and summarised in table 4.18. Each item had a positive correlation with total scale score and 18 out of the 19 coefficients were significant. Inter-item correlations for the SSI ranged from 0.01 to 0.58 with an average inter-item correlation of 0.22. The standardized Cronbach's alpha for the individual items were 0.82.

Table 4.19 Varimax-rotated component analysis factor matrix (n=447)

Item	Varimax-rotated factor loadings[a]			Communality
	Factor I	**Factor II**	**Factor III**	**(h^2)**
Wish to live	0.596	-0.166	0.237	0.439
Wish to die	0.699	-0.051	0.013	0.491
Reason for living or dying	-0.080	-0.064	0.640	0.420
Actual suicide desire	0.756	0.197	-0.057	0.614
Passive suicide desire	0.522	-0.161	0.336	0.411
Duration	0.601	-0.125	0.281	0.456
Frequency	0.551	0.041	0.197	0.344
Attitude toward ideation	0.548	0.206	0.385	0.456
Control over action	0.124	0.246	0.720	0.491
Deterrents to attempt	0.336	0.380	0.530	0.538
Reason for attempt	0.292	0.226	0.205	0.177
Specificity of planning	0.642	0.488	-0.123	0.665
Availability and opportunity	0.259	0.583	-0.085	0.414
Capacity	-0.014	0.699	0.365	0.622
Expectancy	0.486	0.481	0.225	0.517
Actual preparation	0.581	0.315	0.044	0.439
Suicide note	-0.026	0.702	0.072	0.499
Final acts	0.099	-0.149	0.206	0.075
Deception or concealment	-0.080	0.141	0.330	0.135
				Total
Eigen value	3.94	2.35	2.05	8.34

[a] Factor loadings greater than 0.4 have been underlined

Unrotated factor analysis resulted in cross loadings on *wish to die*, *specificity of planning*, *control over action* and *capacity*. Varimax and oblique rotation was applied. Items with significant factor loadings were retained i.e. factor loadings greater than 0.4. Table 4.19 summarises varimax-rotated principal component analysis factor matrix. *Reason for attempt, final acts* and *deception or concealment* had low communalities and did not have significant factor loadings and were therefore removed from further analysis. In addition *specificity of planning* and *expectancy* was removed due to cross-loadings and the analysis repeated.

The three factors were represented by the following items:

a) Factor I – Wish to live, wish to die, active suicidal desire, passive suicidal desire, duration, frequency, attitude toward ideation and actual preparation

b) Factor II – Availability and opportunity, capacity and suicide note

c) Factor III – Reason for living or dying, control over action and deterrents to attempt

Compared to the original factors reported by Beck *et al* (1979), factor I corresponded with six out of the ten items, factor II corresponded with one out of the three items and factor III corresponded with none of the three items. Compared to the original factors reported by Steer *et al* (1993), factor I corresponded with four out of the five items, factor II corresponded with three out of the seven items and factor III corresponded with one out of the four items.

Standardised Cronbach's alpha coefficients of factors I to III of the summated scale was 0.54, 0.57 and 0.37 respectively. All three factors were below the recommended 0.7 cut-off. Overall, the test scale has an alpha coefficient of 0.60 for the constructed three factors of SSI scale, with an average inter-item correlation of 0.33. This finding was lower than the alpha coefficient of 0.89 reported by Beck *et al* (1979) and 0.90 by Steer *et al* (1993).

4.4.1.4 Confirmatory factor analysis

Three measurement models of suicide were compared to identify the best model with construct validity i.e. standardised loading estimates greater than 0.5 and internal reliability of greater than 0.70. Model A was derived from the factors extracted by principal component factor analysis with varimax rotation. Model B was derived from the original factors reported by Steer *et al* (1993). Model C was derived from the original factors reported by Beck *et al* (1979).

Overall, the internal reliability of model B was considered adequate (3-factors, Cronbach's $\alpha = 0.75$). The internal reliability of the individual factors I to III of model B were 0.66, 0.76 and 0.58 respectively. For model C, the internal reliability was less than adequate (3-factors, Cronbach's $\alpha = 0.65$), with the internal reliability of the individual factors I to III were 0.44, 0.55 and 0.66 respectively.

Goodness-of-fit statistics of the models A to C were evaluated by confirmatory factor analysis. Figures 4.6 to 4.8 represent the visual representation (path diagrams) of three measurement models (A to C) for the latent construct suicidal ideation.

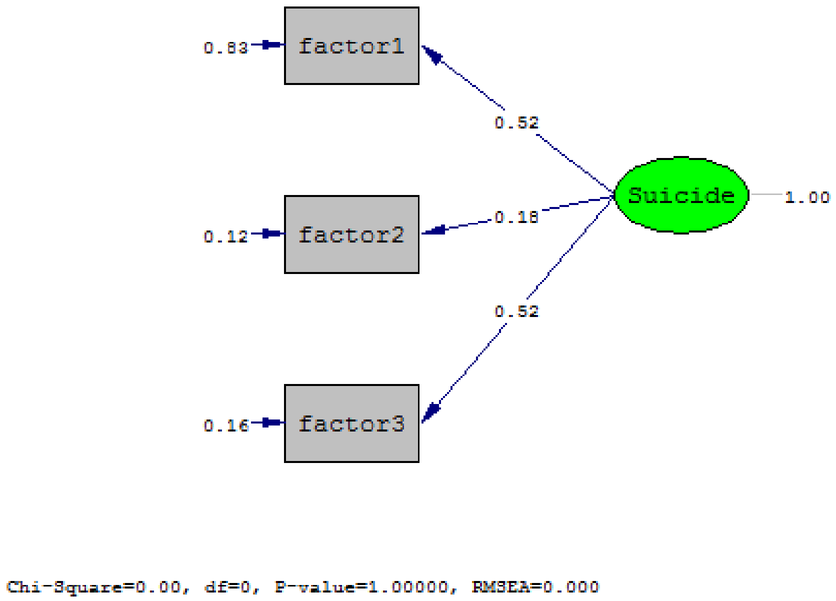

Figure 4.6 CFA of suicide factors derived by factor analysis (A)

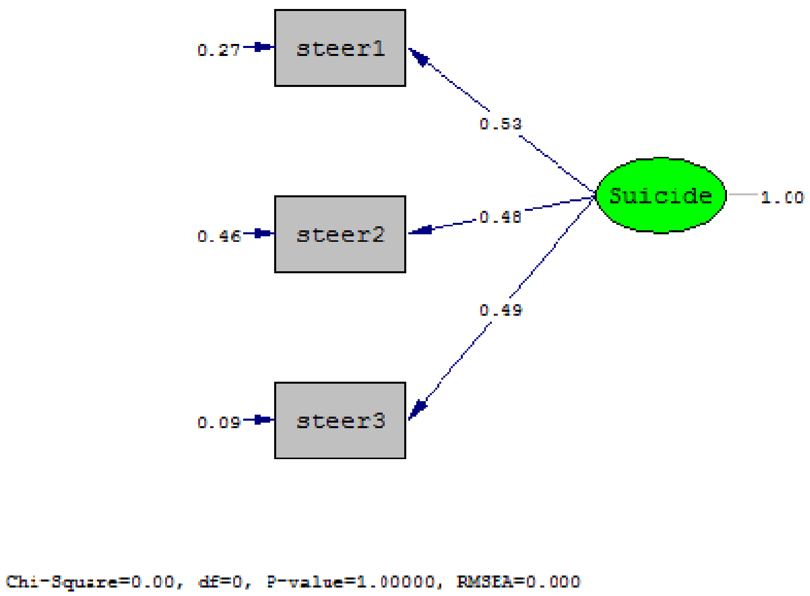

Figure 4.7 CFA of suicide factors derived by Steer *et al* (1993) (B)

The standardised loading estimates of suicide model A was 0.50, 0.46 and 0.80, model B was 0.72, 0.57 and 0.85 and model C were 0.81, 0.61 and 0.46, suggesting that model B had better construct validity.

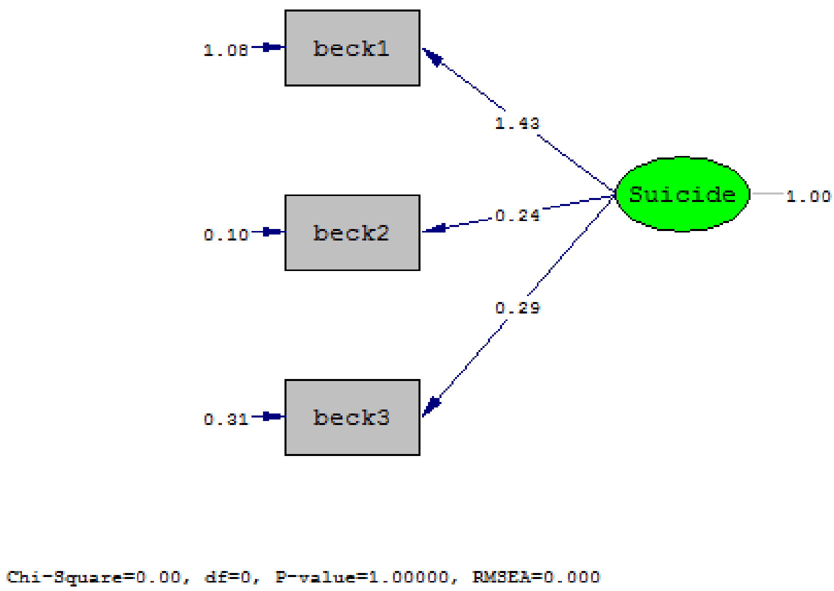

Figure 4.8 CFA of suicide factors derived by Beck *et al* (1979) (C)

The goodness-of-fit statistics shown in figures 4.6 to 4.8 revealed all three models had zero degrees of freedom and chi-square thus generating a saturated model where the observed and estimated covariance matrices agree, i.e. perfect fit. This would imply that the three item models were "just-identified" for the measurement models of the SSI. Our analysis suggests that a scale with more than three factors may have yielded a better fit as indicated by the scree plot (figure 4.5) where the extraction of four factors was recommended. However, an a priori approach was undertaken based on the three factor models reported by Beck *et al* (1979) and Steer *et al* (1993).

4.4.1.5 Summary

Model B was the only model with an internal consistency of greater than 0.70. In addition model A and B had standardised loading estimates of greater than 0.50. Therefore model B i.e. derived from the original factors reported by Steer *et al* (1993) was considered the suicide model with the best construct validity and was included for SEM analysis.

4.4.2 Reliability Analysis

The internal consistency of the four scales (BIS-11, SSI, BSI, GHQ-28) was measured by calculating the inter-item correlation and the Cronbach's alpha coefficient (ranging from 0 to 1). Item-test correlations show how highly correlated each item is with the overall scale and item-rest correlations show how the item is correlated with a scale computed from the remaining items. Estimated Cronbach's alpha coefficients of 0.7 to 0.8 was considered "adequate" and more than 0.8 was considered "good" scales.

4.4.2.1 General health questionnaire (GHQ-28)

The scale consisted of 28 items within four GHQ subscales i.e. somatic symptoms, anxiety and insomnia, social dysfunction and severe depression. The standardised Cronbach's alpha for the GHQ-28 was 0.72. The scale had an "adequate" internal reliability.

The inter-item correlations among the four subscales were positive. By removing the individual subscales, the Cronbach's alpha coefficient would increase or decrease as follows: somatic symptoms subscale, 0.61; anxiety and insomnia subscale, 0.57; social dysfunction subscale, 0.76 and severe depression subscale, 0.64. In examining the item-rest correlation, the social dysfunction subscale had the lowest correlation (0.31). By removing social dysfunction subscale, the Cronbach's alpha coefficient would increase to 0.76.

4.4.2.2 Brief symptom inventory (BSI)

The scale consisted of 53 items within nine primary symptom dimensions i.e. somatisation, obsessive-compulsive behaviour, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation and psychoticism. The standardised Cronbach's alpha coefficient for the BSI was 0.91. The scale had a "good" internal reliability which was higher than the Cronbach's alpha coefficients of nine subscales of 0.71 to 0.85 by Derogatis and Meliseratos (1983).

The inter-item correlations among the factors were positive. By removing the individual subscales, the Cronbach's alpha coefficient would increase or decrease as follows: somatisation subscale, 0.91; obsessive-compulsive behaviour subscale, 0.90; interpersonal sensitivity subscale, 0.90; depression subscale, 0.90; anxiety subscale, 0.90; hostility subscale, 0.91; phobic anxiety subscale, 0.90; paranoid ideation subscale, 0.90 and psychoticism subscale, 0.90. The removal of any subscale was not suggested as the alpha coefficient did not increase with deletion of any of the items.

4.4.2.3 Barratt's impulsivity scale (BIS-11)

The scale consisted of 30 items within three subscales i.e. attention impulsiveness, motor impulsiveness and non-planning impulsiveness. The standardised Cronbach's alpha for the BIS-11 was 0.69, which may be considered "adequate". This was lower than the Cronbach's alpha coefficients of 0.79 to 0.83 for the three subscales reported by Patton *et al* (1995).

The inter-item correlations among the 3 items were positive. The Cronbach's alpha coefficient would increase or decrease by removing the individual subscales as follows: attention impulsiveness subscale, 0.57; motor impulsiveness subscale, 0.66 and non-planning impulsiveness subscale, 0.44. Therefore the removal of any of the subscales was not suggested as the alpha coefficient did not increase with item deletion.

4.4.2.4 Beck's scale of suicidal ideation (SSI)

The scale consists of 19 items. The standardised Cronbach's alpha for the SSI with 19 individual items was 0.82.

The internal reliability of the three versions of the subscales for the SSI was:

a) Three items derived by factor analysis; (3-items, Cronbach's $\alpha = 0.60$)
b) Original factors reported by Beck *et al* (1979); (3-items, Cronbach's $\alpha = 0.65$)
c) Original factors reported by Steer *et al* (1993); (3-items, Cronbach's $\alpha = 0.75$)

The standardised Cronbach's alpha coefficient for the summated scale developed by factor analysis (section 4.4.1.4) was 0.60 and was considered "less than adequate". In addition, the alpha coefficient was lower than that found by Beck *et al* (1979) and Steer *et al* (1993) with reliability coefficients of 0.89 and 0.90 respectively.

4.4.2.5 CAGE score

The CAGE questionnaire was considered reliable (4-items, Cronbach's $\alpha = 0.76$).

4.4.2.5 Summary of reliability analysis

The internal reliability of the instruments was considered “adequate” for the GHQ-28 (4-items, Cronbach’s $\alpha = 0.72$), BIS-11(3-items, Cronbach’s $\alpha = 0.69$) and CAGE questionnaire (4-items, Cronbach’s $\alpha = 0.76$). The internal reliability was considered “good” for the BSI questionnaire (9-items, Cronbach’s $\alpha = 0.91$). With regard to the SSI, the subscales derived by Steer *et al* (1993) (3-items, Cronbach’s $\alpha = 0.75$) was considered reliable and was used in the SEM analysis.

4.4.3 Structural Equation Modelling

4.4.3.1 An approach to model building

Three models hypothesised possible causal pathways in which exposure to low dose OP pesticides were implicated for development of depression, impulsive behaviour and suicidal ideation as outcomes.

Several steps were involved in estimating the structural equation models (table 4.20). The measurement and structural models were evaluated in male subset of the study population (n=477). The complete goodness-of-fit statistics were not reported by the LISREL program when models were adjusted by cluster sampling. Therefore all models were evaluated with and without the effect of cluster sampling by farms in order to adequately select the best models by comparing the full goodness-of-fit statistics. Hypothesis 1 was represented by Models A to D; hypothesis 2 was represented by models E and F and hypothesis 3 was represented by models G to L. Each hypothesis was evaluated by two exposure variables i.e. cumulative years exposed while working in the agricultural sector (a single item construct) and a combination of eight-item constructs (eight pesticide applicator / farming activities).

Depressive symptoms were measured using the four subscales of the GHQ-28 and nine subscales of the BSI questionnaire in section 4.4.3.4 (model 1) and section 4.4.3.6 (model 3). In section 4.4.3.7, the depression subscale was used to replace the four subscales of the GHQ-28 questionnaire in a variant of models A and I (labelled models A2 and I2, respectively, for a more accurate definition of depressive symptoms). Models A to L are summarised in appendix A and models A2 and I2 are summarised in appendix B.

Table 4.20 Outline of SEM model building

Models	OP exposure variables	Instruments		
		Depressive symptoms	Impulsive behaviour	Suicidal ideation
Hypothesis 1				
Model A	Cumulative years exposed	GHQ-28	-	SSI
Model B	8 farming/spraying activities	GHQ-28	-	SSI
Model C	Cumulative years exposed	BSI	-	SSI
Model D	8 farming/spraying activities	BSI	-	SSI
Hypothesis 2				
Model E	Cumulative years exposed	-	BIS-11	SSI
Model F	8 farming/spraying activities	-	BIS-11	SSI
Hypothesis 3				
Model G (1)	Cumulative years exposed	GHQ-28	BIS-11	SSI
Model H (2)	Cumulative years exposed	GHQ-28	BIS-11	SSI
Model I (3)	Cumulative years exposed	GHQ-28	BIS-11	SSI
Model J (1)	8 farming/spraying activities	GHQ-28	BIS-11	SSI
Model K (2)	8 farming/spraying activities	GHQ-28	BIS-11	SSI
Model L (3)	8 farming/spraying activities	GHQ-28	BIS-11	SSI
Alternative models				
Model A2	Cumulative years exposed	Depression subscale (GHQ)	–	SSI
Model I2 (3)	Cumulative years exposed	Depression subscale (GHQ)	BIS-11	SSI

(1) - Adjusted for confounders on depression, (2) - adjusted for confounders on impulsivity, (3) - adjusted for confounders on both depression and impulsivity

4.4.3.2 Measurement models

Measurement models for each hypothesis (chapter 3, table 3.3 and table 3.4) were evaluated first to establish goodness-of-fit before adding structural paths. The goodness-of-fit statistics for measurement models A to L are presented below (table 4.21). As indicated earlier, the sample size was based on the male subsample (n=447). Cluster sampling by farms was excluded in this analysis as the LISREL program did not produce the full goodness-of-fit output measures i.e. only absolute fit measures were produced when cluster sampling was taken into account. All models had significant chi-square tests. Sensitivity to sample sizes more than 200 is a known limitation to the chi-square test where p-values become significant as sample size increases (Hoe, 2008). However, a χ^2/df of less than three suggested by Kline (2005) is considered a good indicator of absolute model fit. The RMSEA scores were less than 0.08 for all models. CFI and NNFI were greater than 0.90. All measured variables loaded significantly on the respective latent constructs of each model. In addition, standardised path estimates between constructs in each model were less than one and there was an absence of Heywood cases i.e. a negative error variance estimate. Therefore all models were considered valid and acceptable to continue to include structural paths.

Table 4.21 Goodness-of-fit statistics of measurement models A to L (n=447)

Models	Absolute fit measures						Incremental fit		Parsimony fit
	X^2	*df*	X^2/df	*p*-value	RMSEA	RMSEA (90% CI)	CFI	NNFI	PNFI
Hypothesis 1									
A	136.21	73	1.87	<0.001	0.044	(0.032 – 0.055)	0.97	0.96	0.65
B	342.13	191	1.79	<0.001	0.042	(0.035 – 0.049)	0.97	0.97	0.77
C	316.84	153	2.07	<0.001	0.049	(0.041 – 0.057)	0.98	0.97	0.77
D	574.18	306	1.88	<0.001	0.044	(0.039 – 0.049)	0.97	0.97	0.82
Hypothesis 2									
E	88.90	60	1.48	0.009	0.033	(0.017 – 0.047)	0.98	0.98	0.63
F	285.67	171	1.67	<0.001	0.039	(0.031 – 0.047)	0.98	0.97	0.77
Hypothesis 3									
G	221.99	111	1.99	<0.001	0.047	(0.038 – 0.056)	0.96	0.95	0.67
H	221.99	111	1.99	<0.001	0.047	(0.038 – 0.056)	0.96	0.95	0.67
I	221.99	111	1.99	<0.001	0.047	(0.038 – 0.056)	0.96	0.95	0.67
J	455.75	250	1.82	<0.001	0.043	(0.037 – 0.049)	0.97	0.96	0.77
K	455.75	250	1.82	<0.001	0.043	(0.037 – 0.049)	0.97	0.96	0.77
L	455.75	250	1.82	<0.001	0.043	(0.037 – 0.049)	0.97	0.96	0.77

4.4.3.3 Structural Models

The goodness-of-fit for the models are described in the section below when taking into account cluster sampling by farms and no cluster sampling (tables 4.22 and 4.23). Model selection was based on the assessment of "good" fit and significant path estimates for both versions of OP exposure variables i.e. cumulative years exposed and the time exposed during a combination of eight farming activities. Models A to L are presented in Appendix A when accounting for cluster sampling by farms.

Table 4.22 presents the goodness-of-fit statistics of models A to L when taking into account clustering by farms. The following model fit outputs were presented: chi-square test, ratio of chi-square to degrees of freedom (χ^2/df) and RMSEA. All models had a "good fit" with non-significant chi-square tests, χ^2/df less than three and RMSEA less than 0.08.

Table 4.22 Goodness-of-fit statistics of models A to L taking into account cluster sampling by farms (n=447)

Models	Absolute fit measures					
	X^2	*df*	X^2/df	p-value	RMSEA	RMSEA (90% CI)
Hypothesis 1						
A	51.92	78	0.67	0.990	0.00	(0.0 - 0.0)
B	122.50	196	0.63	1.000	0.00	(0.0 - 0.0)
C	120.74	158	0.76	0.988	0.00	(0.0 - 0.0)
D	198.39	311	0.64	1.000	0.00	(0.0 - 0.0)
Hypothesis 2						
E	32.478	65	0.50	1.000	0.00	(0.0 - 0.0)
F	102.35	176	0.58	1.000	0.00	(0.0 - 0.0)
Hypothesis 3						
G	94.711	119	0.80	0.951	0.00	(0.0 - 0.0)
H	94.711	119	0.80	0.951	0.00	(0.0 - 0.0)
I	96.734	115	0.84	0.891	0.00	(0.0 - 0.016)
J	192.082	258	0.74	0.999	0.00	(0.0 - 0.0)
K	175.89	258	0.68	1.000	0.00	(0.0 - 0.0)
L	178.126	254	0.70	1.000	0.00	(0.0 - 0.0)

Table 4.23 Goodness-of-fit statistics of models A to L with no cluster sampling (n=447)

Models	Absolute fit measures						Incremental fit		Parsimony
	X^2	*df*	X^2/df	p-value	RMSEA	RMSEA (90% CI)	CFI	NNFI	PNFI
Hypothesis 1									
A	73.031	29	2.52	<0.001	0.058	(0.050-0.987)	0.971	0.946	0.503
B	275.060	127	2.17	<0.001	0.049	(0.041-0.057)	0.971	0.965	0.787
C	330.022	158	2.09	<0.001	0.049	(0.042-0.057)	0.974	0.968	0.791
D	586.797	311	1.89	<0.001	0.045	(0.039-0.050)	0.972	0.968	0.835
Hypothesis 2									
E	95.501	65	1.47	0.008	0.032	(0.017 - 0.046)	0.983	0.976	0.678
F	206.709	111	1.86	<0.001	0.042	(0.033 - 0.051)	0.980	0.975	0.782
Hypothesis 3									
G	248.093	119	2.08	<0.001	0.049	(0.041 - 0.058)	0.954	0.941	0.713
H	248.093	119	2.08	<0.001	0.049	(0.041 - 0.058)	0.954	0.941	0.713
I	228.239	115	1.98	<0.001	0.047	(0.038 - 0.051)	0.960	0.946	0.694
J	490.698	258	1.90	<0.001	0.045	(0.039 - 0.051)	0.962	0.956	0.794
K	486.208	258	1.88	<0.001	0.045	(0.038 - 0.051)	0.963	0.957	0.795
L	503.643	254	1.98	<0.001	0.047	(0.033 - 0.051)	0.959	0.952	0.780

Table 4.23 presents the complete goodness-of-fit output of models A to L without the effect of cluster sampling. Though the chi-square tests for the models were significant, the ratio of the chi-square to degrees of freedom (χ^2/df) test was less than three and the RMSEA was less than 0.08. CFI and the NNFI were greater than 0.90 suggesting that all models had "good fit". Therefore the structural models were assessed as valid. Two models were selected as final models for each hypothesis where OP exposure was measured as cumulative years exposed and the time exposed during a combination of eight farming/spraying activities.

4.4.3.4 Model 1 (A to D)

The first hypothesis in this study sets out to test whether low dose chronic OP exposure in adult farm workers was directly associated with increased levels of depression, resulting in an increased risk of suicidal ideation. In models A and C, OP exposure was measured by cumulative years exposed. In models B and D, OP exposure was measured by the time exposed during a combination of eight farming/spraying activities. Depression was measured by the GHQ-28 questionnaire in models A and B and BSI questionnaire in models C and D. The measurement and structural model parameter estimates and path diagrams of SEM models A to D are summarised in Appendix A.

All four models met the criteria for "good" fit when taking into account cluster sampling by farms (table 4.22). Of models A and C, model A had lower chi-square test and lower ratio of chi-square to degrees of freedom (χ^2/df) and higher *p*-value than model C. Of models B and D, model B had a lower chi-square test and lower ratio of chi-square to degrees of freedom (χ^2/df) and higher *p*-value than model D. Therefore models A and B were considered final models for hypothesis 1 (for each exposure variable) and are presented below. When analysing the path estimates for each of the four models, results revealed the following standardised path coefficients between OP exposure and depressive symptoms for models:

A: ($P_{DS,\ OPx} = 0.07$, $t = 0.778$, $p = 0.25$),

B: ($P_{DS,\ OPx} = -0.152$, $t = -2.417$, $\underline{p = 0.01}$),

C: ($P_{DS,\ OPx} = 0.01$, $t = 0.121$, $p > 0.25$),

D: ($P_{DS,\ OPx} = -0.102$, $t = -1.372$, $p = 0.10$).

Model B had a significant negative association between OP exposure and depressive symptoms. There was no significant association between OP exposure and depressive symptoms in models A, C and D.

i. Model A

Figure 4.9 demonstrates the pathways of model A. The GOF statistics are: χ^2 = 51.92, *df* = 78, χ^2 /*df* = 0.67, p=0.990 and RMSEA = 0. The additional GOF statistics (when cluster sampling was removed) were CFI=0.97, NNFI = 0.95, PNFI = 0.50).

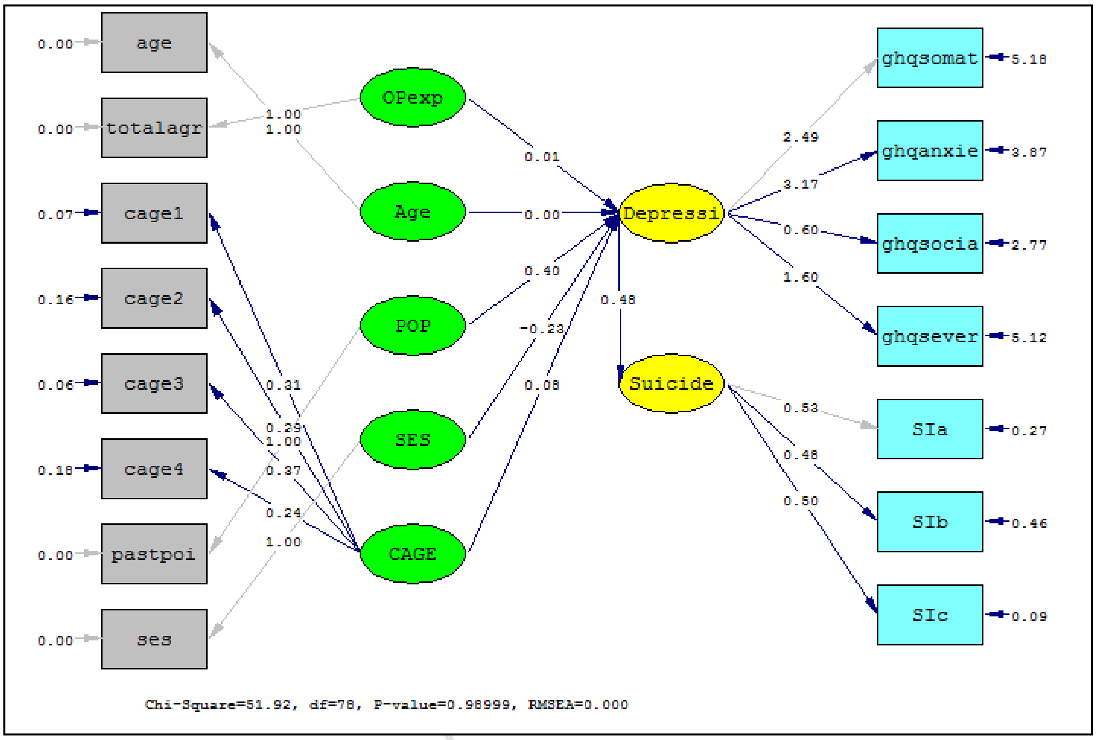

Figure 4.9 Path estimates of model A

Table 4.24 summarises the structural and measurement model path estimates for model A. All measurement model path estimates loaded significantly on its respective latent construct i.e. CAGE score, depression and suicide. The structural model path estimates revealed the following significant relationships:

a) There was no association between cumulative years exposed to pesticides while working in agriculture and depressive symptoms ($P_{DS, OPx}$ = 0.07, t = 0.778, p = 0.50),

b) Male farm workers with a history of previous pesticide poisoning was positively associated with depressive symptoms ($P_{DS, POP}$ = 0.146, t = 2.786, p = 0.05) i.e. the risk of depression increased by 15% in male farm workers with a history of past OP poisoning.

c) Depressive symptoms was positively associated with suicidal ideation ($P_{S, DS}$ = 0.478, t = 2.162, p = 0.05).

Table 4.24 Measurement and structural model estimates of model A

Path	Path coefficient		Standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Cage 1 → CAGE	0.308	0.750	-0.028	11.176	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.410	<0.001
Cage 3 → CAGE	0.373	0.842	-0.018	21.014	<0.001
Cage 4 → CAGE	0.243	0.495	-0.021	11.684	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.486	0.737	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.175	0.850	-0.212	14.973	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.603	0.341	-0.178	3.384	<0.001
GHQ subscale D (Severe depression) → Depression	1.598	0.576	-0.272	5.869	<0.001
SI subscale A (Desire for death) → Suicide	0.529	0.710	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.479	0.576	-0.131	3.648	<0.001
SI subscale C (Active suicide desire) → Suicide	0.496	0.855	-0.036	13.706	<0.001
Structural model estimates					
Age → Depression	0.001	0.001	0.008	0.013	>0.500
Socioeconomic status → Depression	-0.232	-0.113	0.127	-1.833	0.100
CAGE → Depression	0.085	0.085	0.051	1.669	0.100
Past history of OP poisoning → Depression	0.401	0.146	0.144	2.786	0.050
OP exposure → Depression	0.006	0.071	0.008	0.778	0.500
Depression → Suicide	0.478	0.478	-0.221	2.162	0.050

ii. Model B

Figure 4.10 demonstrates the pathways of model B. The GOF statistics were as follows: χ^2 = 122.50, *df* =196, p=1.00; ratio of chi-square to degrees of freedom (χ^2/df = 0.63) and RMSEA = 0. The additional GOF statistics (when cluster sampling was removed) were CFI=0.97, NNFI = 0.97, PNFI = 0.79). The above indices represent a “good” fit.

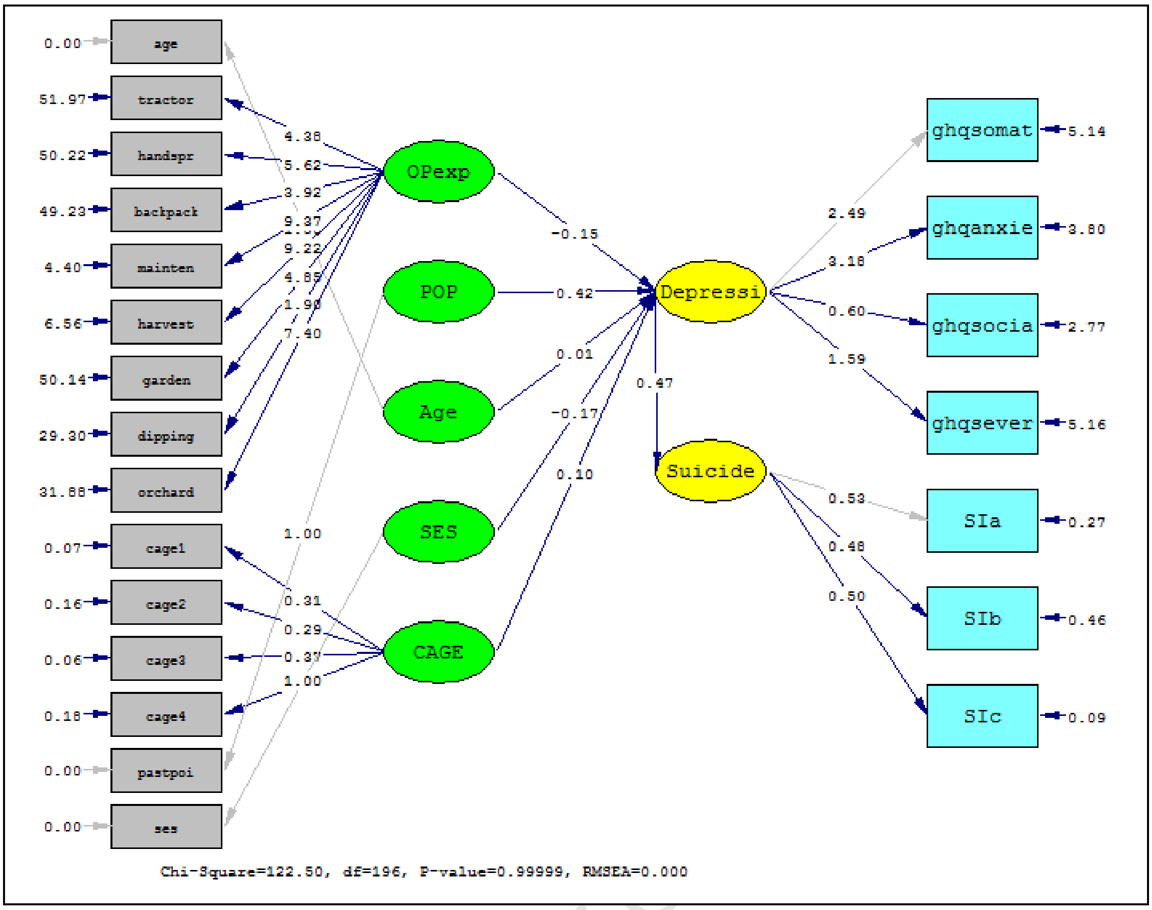

Figure 4.10 Path estimates of Model B

Table 4.25 summarises the structural and measurement model path estimates for model B. All measurement model path estimates loaded significantly on its respective latent constructs i.e. OP exposure, CAGE score, depression and suicide.

Structural model path estimates revealed the following significant relationships:

a) OP exposure measured by eight pesticide applicator / farming activities was negatively associated with depressive symptoms ($P_{DS,\ OPx}$ = -0.152, t=-2.417, p = 0.01) i.e. for every year worked in agriculture (exposed to OP pesticides), the risk of developing depression decreased by 15%.

b) Male farm workers with alcohol related problems i.e. a positive CAGE score, were positively associated with depressive symptoms ($P_{DS,\ CAGE}$ = 0.103, se = 0.052, t = 1.982, p = 0.05).

c) Male farm workers with a history of past pesticide poisoning was positively associated with depressive symptoms ($P_{DS,\ POP}$ = 0.154, se = 0.153, t = 2.770, p =

0.01) i.e. the risk of depression increased by 15% in male farm workers with a history of past poisoning.

d) Depressive symptoms was positively associated with suicidal ideation ($P_{S,\ DS}$ = 0.474, se = -0.219, t = 2.159, p = 0.05).

Table 4.25 Measurement and structural model estimates of model B

Path	**Path coefficient**		**standard error**	***t*-score**	**p-value**
	Unstandardised	**standardised**			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.383	0.520	-0.701	6.527	<0.001
Hand spraying pesticides → OP exposure	5.623	0.622	-0.838	6.707	<0.001
Spraying pesticides using a backpack → OP exposure	3.920	0.488	-0.748	5.243	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.253	<0.001
Harvesting → OP exposure	9.220	0.964	-0.529	17.444	<0.001
Gardening → OP exposure	4.849	0.565	-0.834	5.882	<0.001
Dipping livestock → OP exposure	1.900	0.331	-0.600	3.169	0.010
Orchards → OP exposure	7.403	0.795	-0.657	11.270	<0.001
Cage 1 → CAGE	0.308	0.750	-0.028	11.180	<0.001
Cage 2 → CAGE	0.288	0.586	-0.023	12.278	<0.001
Cage 3 → CAGE	0.374	0.843	-0.018	20.903	<0.001
Cage 4 → CAGE	0.242	0.493	-0.021	11.625	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.494	0.739	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.185	0.853	-0.210	15.141	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.598	0.338	-0.177	3.382	<0.001
GHQ subscale D (Severe depression) → Depression	1.568	0.572	-0.270	5.871	<0.001
SI subscale A (Desire for death) → Suicide	0.530	0.711	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.479	0.577	-0.131	3.648	<0.001
SI subscale C (Active suicide desire) → Suicide	0.496	0.855	-0.036	3.648	<0.001
Structural model estimates					
Age → Depression	0.012	0.139	0.007	1.867	0.100
Socioeconomic status → Depression	-0.174	-0.085	0.130	-1.338	0.200
CAGE → Depression	0.103	0.103	0.052	1.982	0.050
Past history of OP poisoning → Depression	0.424	0.154	0.153	2.770	0.010
OP exposure → Depression	-0.152	-0.152	0.063	-2.417	0.010
Depression → Suicide	0.474	0.474	-0.219	2.159	0.050

4.4.3.5 Model 2 (E and F)

The second hypothesis in this study set out to test whether low dose chronic OP exposure in adult farm workers are directly associated with increased levels of impulsivity, resulting in an increased risk of suicidal ideation. Impulsivity was measured using Beck's Impulsivity Scale (BIS-11). OP exposure was measured by cumulative years exposed in model E and by the time exposed performing any of eight farming / spraying activities, combined into one measure in model F. The measurement and structural model parameter estimates and path diagrams of models E and F are presented below.

Models E and F both met the criteria for "good" fit when taking into account cluster sampling by farms (table 4.20). Both models had relatively low chi-square tests and low ratio of chi-square to degrees of freedom (χ^2/df) and p-values of 1. Therefore models E and F were considered as equivalent models for hypothesis 2.

When analysing the path estimates for each of the four models, results revealed the following standardised path coefficients between OP exposure and impulsive behaviour for models:

E: ($P_{IB, OPx}$ = -0.107, se=0.006, t=-1.591, p=0.10),

F: ($P_{IB, OPx}$ =-0.097, se=0.055, t=-1.757, p=0.10).

There was no significant association between OP exposure and impulsive behaviour in models E and F.

i. Model E

Figure 4.11 shows the pathways of model E. The GOF statistics are: χ^2 = 32.48, *df* = 65, χ^2 /*df* = 0.50, p = 1.00 and RMSEA = 0. The additional GOF statistics (when cluster sampling was removed) were CFI=0.98, NNFI = 0.98, PNFI = 0.68) which indicates a "good fit".

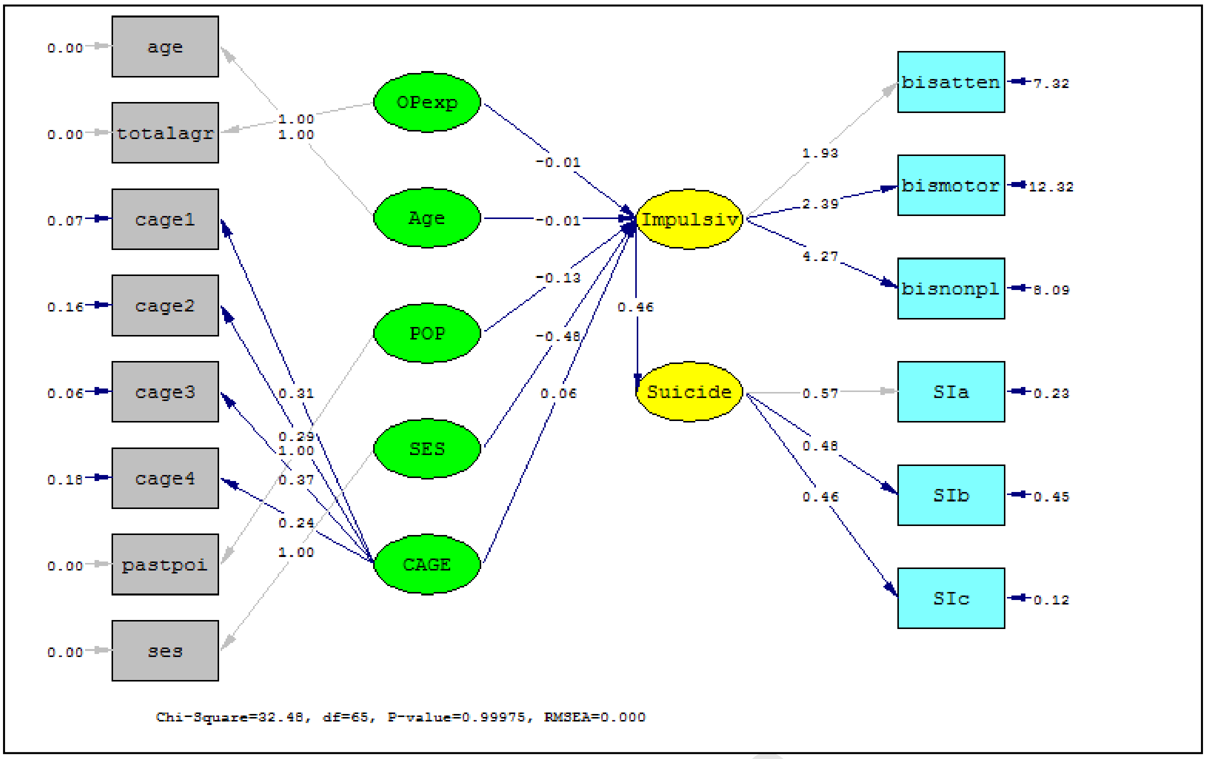

Figure 4.11 Path estimates of model E

Table 4.26 summarises the structural and measurement path estimates of model E. All measurement model path estimates loaded significantly on its respective latent construct i.e. CAGE, impulsive behaviour and suicide. Structural model path estimates revealed the following significant relationships:

a) Socioeconomic score was inversely associated with impulsive behaviour ($P_{IB, SES}$ = -0.235, t = -3.783, p <0.001).

b) Impulsive behaviour was positively associated with suicidal ideation ($P_{S, IB}$ = 0.465, se = -0.100, t = 4.661, p <0.001).

Table 4.26 Measurement and structural model estimates of model E

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Cage 1 → CAGE	0.308	0.751	-0.027	11.267	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.499	<0.001
Cage 3 → CAGE	0.373	0.843	-0.018	21.060	<0.001
Cage 4 → CAGE	0.242	0.492	-0.021	11.593	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.927	0.580	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.395	0.563	-0.278	8.601	<0.001
BIS subscale C (Non-planning impulsiveness) → Impulsivity	4.272	0.832	-0.476	8.983	<0.001
SI subscale A (Desire for death) → Suicide	0.567	0.761	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.485	0.584	-0.141	3.449	<0.001
SI subscale C (Active suicide desire) → Suicide	0.463	0.798	-0.049	9.475	<0.001
Structural model estimates					
Age → Impulsivity	-0.006	-0.066	0.007	-0.834	0.500
Socioeconomic status →Impulsivity	-0.481	-0.235	0.127	-3.783	<0.001
CAGE → Impulsivity	0.064	0.064	0.065	0.976	0.400
Past history of OP poisoning → Impulsivity	-0.129	-0.047	0.140	-0.919	0.400
OP exposure → Impulsivity	-0.009	-0.107	0.006	-1.591	0.200
Impulsivity → Suicide	0.465	0.465	-0.100	4.661	<0.001

ii. Model F

Figure 4.12 shows the pathways of model F. The GOF statistics are: χ^2 = 102.35, *df* = 176, χ^2 /*df* = 0.58, p = 1.00 and RMSEA = 0. The additional GOF statistics (when cluster sampling was removed) were CFI=0.98, NNFI = 0.98, PNFI = 0.78). The above indices represent a model with "good fit".

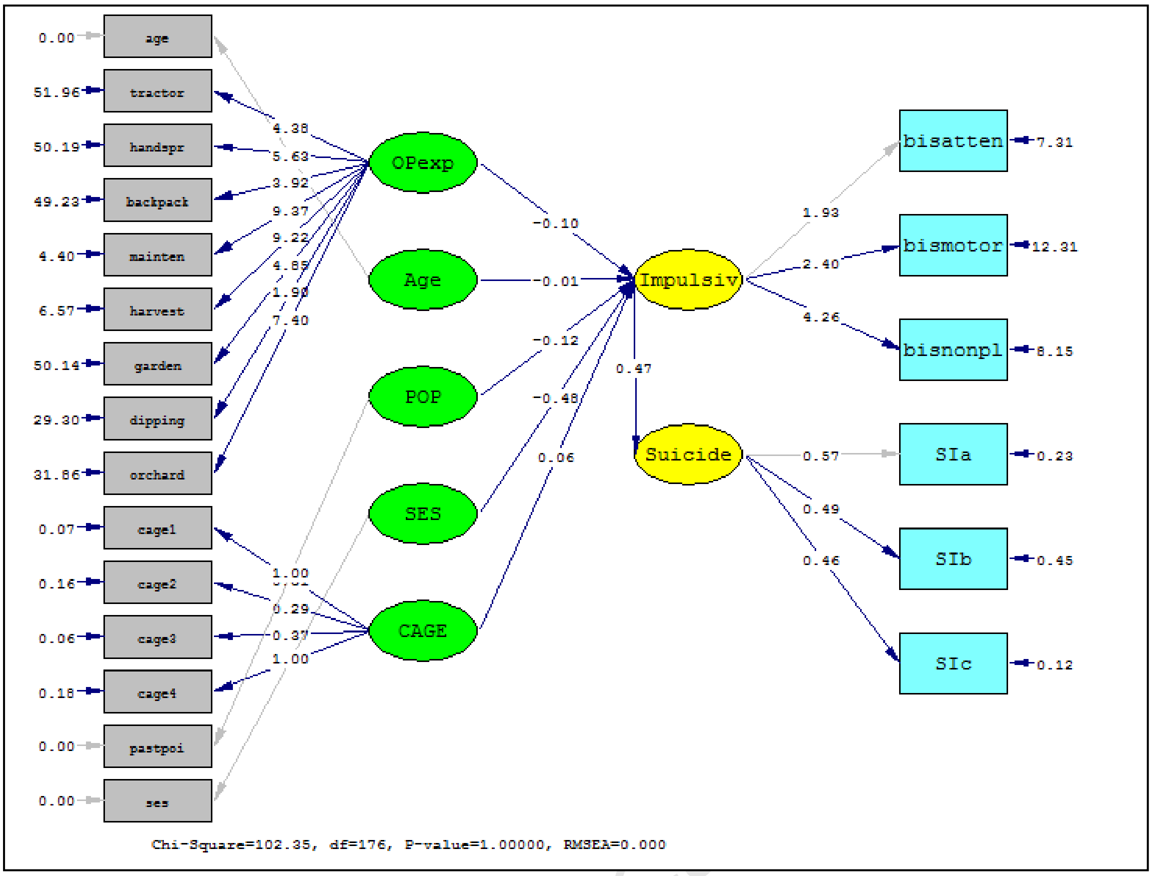

Figure 4.12 Path estimates of F

Table 4.27 summarises the structural and measurement path estimates of model F. All measurement model path estimates loaded significantly on its respective latent construct i.e. OP exposure, CAGE score, impulsive behaviour and suicide. Structural model path estimates revealed the following significant relationships:

a) Socioeconomic score of male farm workers was inversely associated with impulsive behaviour ($P_{IB, SES} = -0.235$, $t = -3.683$, $p < 0.001$).

b) Impulsive behaviour was positively associated with suicidal ideation ($P_{S, IB} = 0.467$, $t = 4.671$, $p < 0.001$).

Table 4.27 Measurement and structural model estimates model F

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.384	0.520	-0.700	6.259	<0.001
Hand spraying pesticides → OP exposure	5.626	0.622	-0.838	6.712	<0.001
Spraying pesticides using a backpack → OP exposure	3.921	0.488	-0.748	5.245	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.266	<0.001
Harvesting → OP exposure	9.219	0.963	-0.528	17.447	<0.001
Gardening → OP exposure	4.849	0.565	-0.834	5.817	<0.001
Dipping livestock → OP exposure	1.899	0.331	-0.599	3.170	0.010
Orchards → OP exposure	7.404	0.795	-0.656	11.280	<0.001
Cage 1 → CAGE	0.308	0.751	-0.027	11.274	<0.001
Cage 2 → CAGE	0.288	0.586	-0.023	12.368	<0.001
Cage 3 → CAGE	0.374	0.844	-0.018	20.943	<0.001
Cage 4 → CAGE	0.241	0.491	-0.021	11.531	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.929	0.580	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.396	0.563	-0.278	8.609	<0.001
BIS subscale C (Non-planning impulsiveness) → Impulsivity	4.264	0.831	-0.469	9.094	<0.001
SI subscale A (Desire for death) → Suicide	0.567	0.762	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.485	0.584	-0.141	3.445	<0.001
SI subscale C (Active suicide desire) → Suicide	0.462	0.797	-0.049	9.402	<0.001
Structural model estimates					
Age → Impulsivity	-0.008	-0.093	0.007	-1.244	0.300
Socioeconomic status →Impulsivity	-0.481	-0.235	0.131	-3.683	<0.001
CAGE → Impulsivity	0.063	0.063	0.065	0.973	0.400
Past history of OP poisoning → Impulsivity	-0.124	-0.045	0.140	-0.886	0.500
OP exposure → Impulsivity	-0.097	-0.097	0.055	-1.757	0.100
Impulsivity → Suicide	0.467	0.467	-0.100	4.671	<0.001

4.4.3.6 Model 3 (I and L)

The third hypothesis in this study set out to test that low dose chronic OP in adult farm workers are directly associated with increased levels of both depression and impulsivity, resulting in an increased risk of suicidal ideation. In addition, an interaction between depression and impulsive behaviour modifies the risk for suicide in adult farm workers exposed to low dose OP pesticides when compared to unexposed farm workers.

As outlined in table 4.20, OP exposure was measured by cumulative years exposed in models G to I and time exposed performing any of eight farming / spraying activities, combined into one measure in models J to L. Depression was measured by the GHQ-28 instead of the BSI. This was based on the selection of models A and B for hypothesis 1 (model 1). Adjustment was made for age, CAGE score, socio-economic status and past history of OP poisoning on depression only in models G and J; on impulsivity only in models H and K; and both impulsivity and depression in models I and L.

The measurement and structural path estimates of models G and L are summarised in Appendix A. All six models (G to L) demonstrated "good" fit i.e. low chi-square test with insignificant p-value, ratio of chi-square to degrees of freedom (χ^2/df) < 3, and RMSEA <0.08 (table 4.22). When summarising the path estimates for each of the six models, the following standardised path coefficients between OP exposure (OPx) and depressive symptoms (DS) and OP exposure (OPx) and impulsive behaviour (IB) are presented below:

G: ($P_{DS, OPx}$ = -0.170, t = -0.758, p = 0.50); ($P_{IB, OPx}$ = -0.323, t = -3.107, <u>p = 0.01</u>)

H: ($P_{DS, OPx}$ = 0.212, t = 2.972, <u>p = 0.01</u>); ($P_{IB, OPx}$ = -0.081, t = -0.926, p =0.40)

I: ($P_{DS, OPx}$ = -0.096, t = 0.111, p > 0.50); ($P_{IB, OPx}$ = -0.119, t = -1.264, p = 0.30)

J: ($P_{DS, OPx}$ = -0.593, t = -1.156, p = 0.30); ($P_{IB, OPx}$ = -0.056, t = -0.498, p > 0.50)

K: ($P_{DS, OPx}$ = 0.085, t = -1.477, p = 0.20); ($P_{IB, OPx}$ = -0.029, t = -0.594, p > 0.50)

L: ($P_{DS, OPx}$ = 0.117, t = -1.740, p = 0.10); ($P_{IB, OPx}$ = -0.116, t = -1.647, p = 0.10)

It should be noted that in Model H, OP exposure and depressive symptoms were positively associated ($P_{DS, OPx}$ = 0.212, t = 2.972, p=0.01). Also in model G, there was a significant negative association between OP exposure and impulsivity ($P_{IB, OPx}$ = -0.323, t = -3.107, p = 0.01). As explained above, in model H the confounders were adjusted on impulsivity and not on depression. Similarly, in model G the confounders were adjusted on depression but not on impulsivity. Therefore the relationship between OP exposure and depression or OP exposure and impulsivity for models G and H became significant based on which construct the confounders were adjusted on. However, models I and L were selected for the final model 3, on the basis that the confounders were adjusted on <u>both</u> depression and impulsivity and would therefore reflect a more accurate association.

i. Model I

Figure 4.13 shows the pathways of model I. The GOF statistics are: χ^2 = 96.734, *df* = 115, χ^2 /*df* = 0.84, p = 0.891 and RMSEA = 0. The additional GOF statistics (when cluster sampling was removed) were CFI=0.96, NNFI = 0.95, PNFI = 0.69) which indicated a “good fit”.

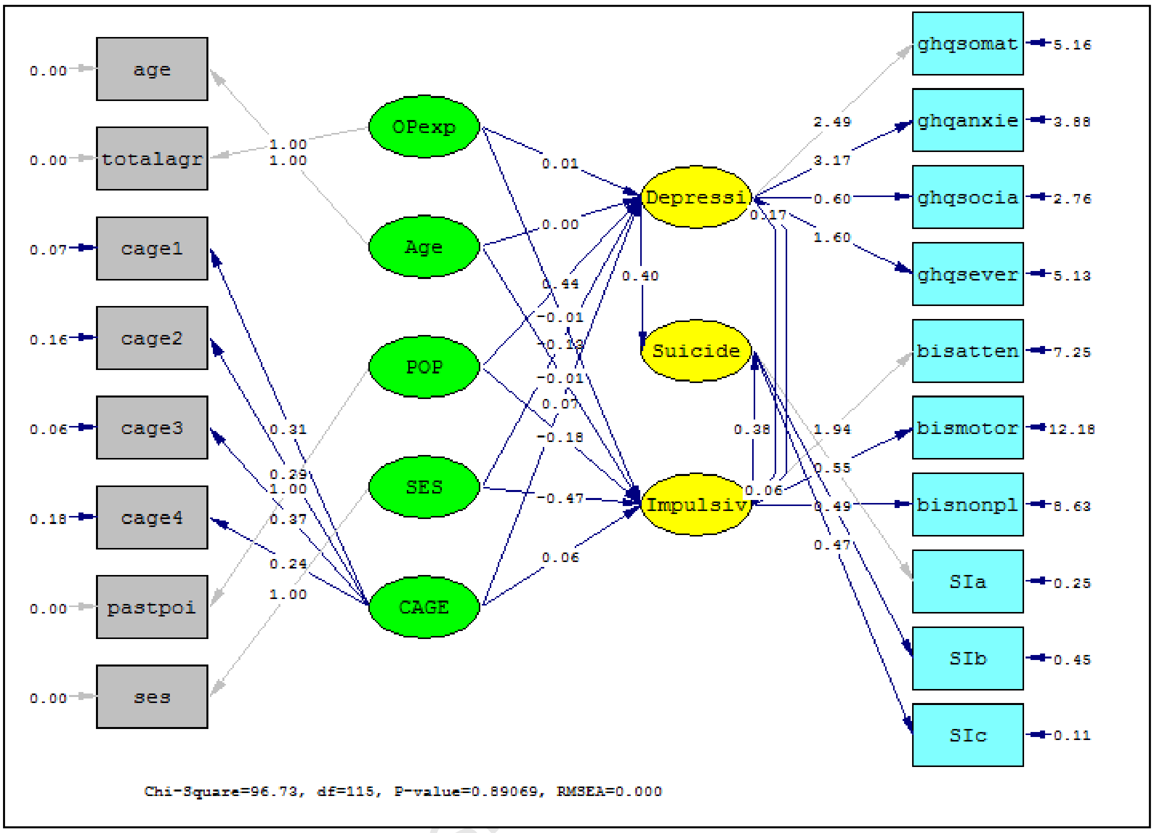

Figure 4.13 Path estimates of model I

Table 4.28 summarises the structural and measurement path estimates of model I. All measurement model path estimates loaded significantly on its respective latent construct i.e. CAGE score, impulsive behaviour, depression and suicide. Structural model path estimates revealed the following significant relationships:

a) Older male farm workers were positively associated with depressive symptoms ($P_{DS,A}$ = 0.015, t = 2.326, p = 0.05).

b) Socioeconomic score was negatively associated with impulsive behaviour ($P_{IB,\ SES}$ = -0.277, t = -2.158, p = 0.05).

c) Depressive symptoms were positively associated with suicidal ideation ($P_{S,\ DS}$ = 0.400, t = 2.096, p = 0.05).

d) Impulsive behaviour was positively associated with suicidal ideation ($P_{S, IB}$ = 0.378, t= 5.991, p <0.001).

Table 4.28 Measurement and structural model estimates of model I

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Cage 1 → CAGE	0.308	0.751	-0.027	11.273	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.510	<0.001
Cage 3 → CAGE	0.373	0.842	-0.018	21.007	<0.001
Cage 4 → CAGE	0.242	0.492	-0.021	11.576	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.491	0.739	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.172	0.849	-0.209	15.140	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.604	0.341	-0.177	3.417	<0.001
GHQ subscale D (Severe depression) → Depression	1.596	0.575	-0.270	5.912	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.944	0.585	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.424	0.570	-0.278	8.723	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.207	0.820	-0.451	9.332	<0.001
SI subscale A (Desire for death) → Suicide	0.554	0.744	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.489	0.589	-0.140	3.485	<0.001
SI subscale C (Active suicide desire) → Suicide	0.472	0.813	-0.046	10.212	<0.001
Structural model estimates					
Age → Depression	0.001	0.015	0.189	2.326	0.050
Age → Impulsivity	-0.006	-0.067	0.007	-0.872	0.400
Socioeconomic status → Depression	-0.132	-0.065	0.074	0.970	0.400
Socioeconomic status → Impulsivity	-0.465	-0.277	0.216	-2.158	0.050
CAGE → Depression	0.072	0.072	0.095	0.700	0.500
CAGE → Impulsivity	0.058	0.058	0.094	0.616	>0.500
Past history of OP poisoning → Depression	0.439	0.016	0.410	-0.322	>0.500
Past history of OP poisoning → Impulsivity	-0.179	-0.065	0.348	-0.515	>0.500
OP exposure → Depression	0.008	0.096	0.012	0.111	>0.500
OP exposure → Impulsivity	-0.010	-0.119	0.008	-1.264	0.300
Depression → Impulsivity	0.056	0.056	-0.788	0.071	>0.500
Impulsivity → Depression	0.173	0.173	-0.796	0.217	>0.500
Depression → Suicide	0.400	0.400	0.191	2.096	0.050
Impulsivity → Suicide	0.378	0.378	0.063	5.991	<0.001

4.3.6.2 Model L

Figure 4.14 shows the pathways of model L. The GOF statistics are: χ^2 = 178.13, *df* = 254, χ^2 /*df* = 0.70, p = 1.00 and RMSEA = 0. The additional GOF statistics (when cluster sampling was removed) were CFI=0.96, NNFI = 0.95, PNFI = 0.78) which indicated a "good fit".

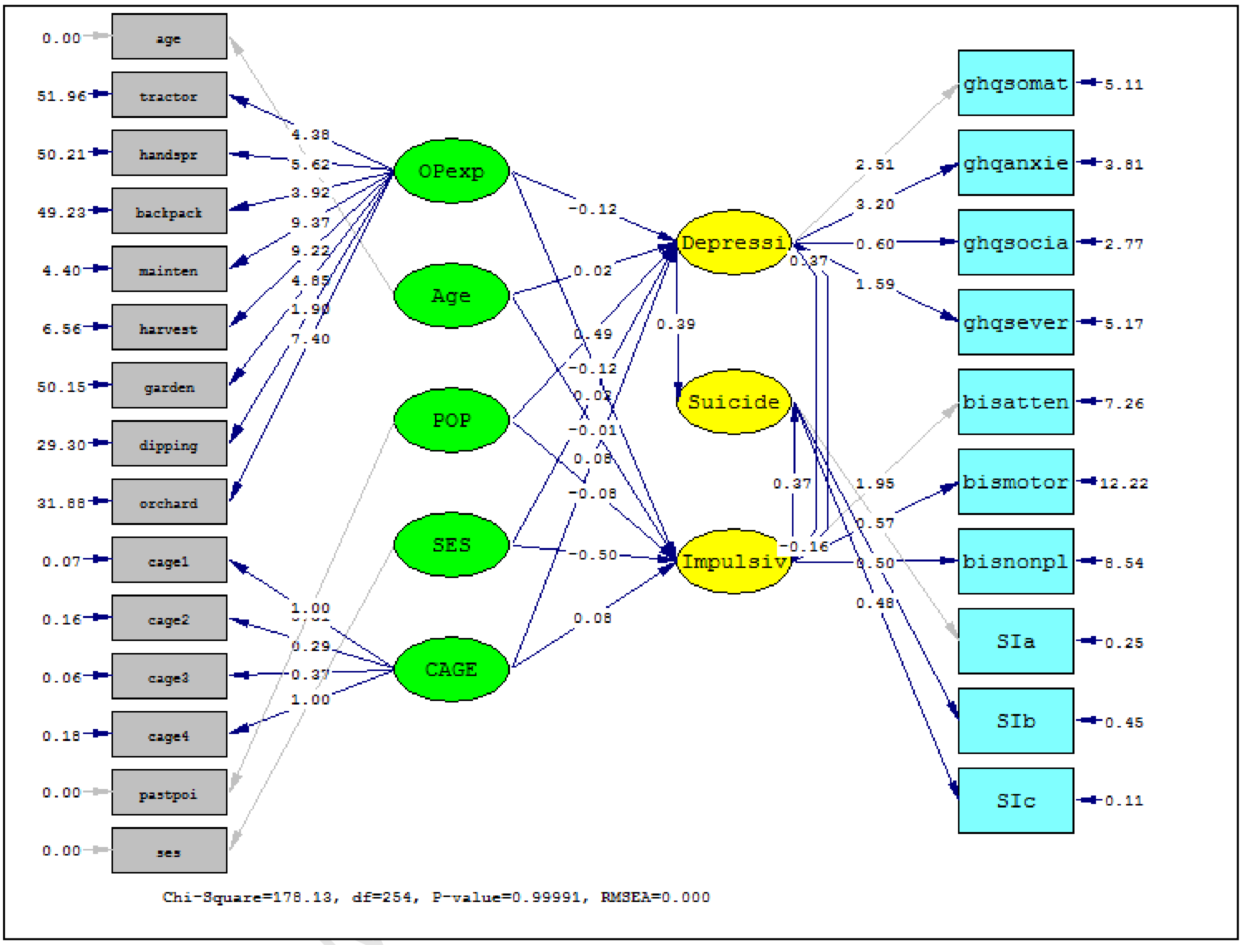

Figure 4.14 Path estimates of model L

Table 4.29 summarises the structural and measurement path estimates of model L. All measurement model path estimates loaded significantly on its respective latent construct i.e. OP exposure, CAGE, impulsive behaviour, depressive symptoms and suicide. Structural model path estimates revealed the following significant relationships:

a) Older male farm workers were positively associated with depressive symptoms ($P_{DS,A}$ = 0.183, t = 2.246, p = 0.05).

b) Low socioeconomic status was positively associated with impulsive behaviour ($P_{IB,SES}$ = -0.247, t = -3.869, p = 0.05).

c) Farm workers with a past history of OP poisoning was positively associated with depressive symptoms ($P_{DS, POP} = 0.178$, $t = 3.269$, $p < 0.001$)

d) Depressive symptoms were positively associated with suicidal ideation ($P_{S, DS} = 0.395$, $t = 2.090$, $p = 0.05$).

e) Impulsive behaviour was positively associated with suicidal ideation ($P_{S, IB} = 0.380$, $t = 6.001$, $p < 0.001$).

Table 4.29 Measurement and structural model estimates of model L

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.384	0.520	-0.700	6.259	<0.001
Hand spraying pesticides → OP exposure	5.626	0.622	-0.838	6.713	<0.001
Spraying pesticides using a backpack → OP exposure	3.921	0.488	-0.747	5.245	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.272	<0.001
Harvesting → OP exposure	9.219	0.963	-0.529	17.443	<0.001
Gardening → OP exposure	4.848	0.565	-0.834	5.816	<0.001
Dipping livestock → OP exposure	1.899	0.331	-0.599	3.170	<0.001
Orchards → OP exposure	7.404	0.795	-0.656	11.281	<0.001
Cage 1 → CAGE	0.308	0.751	-0.027	11.291	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.386	<0.001
Cage 3 → CAGE	0.375	0.843	-0.018	20.909	<0.001
Cage 4 → CAGE	0.241	0.491	-0.021	11.507	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.512	0.741	–	–	–
GHQ subscale B (Anxiety and insomnia) → Depression	3.199	0.852	-0.211	15.182	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.600	0.338	-0.176	3.408	<0.001
GHQ subscale D (Severe depression) → Depression	1.589	0.571	-0.269	5.914	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.953	0.584	–	–	–
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.429	0.568	-0.277	8.763	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.242	0.822	-0.454	9.339	<0.001
SI subscale A (Desire for death) → Suicide	0.568	0.744	–	–	–
SI subscale B (Preparation for suicide) → Suicide	0.501	0.589	-0.144	3.483	<0.001
SI subscale C (Active suicide desire) → Suicide	0.483	0.812	-0.048	10.133	<0.001
Structural model estimates					
Age → Depression	0.016	0.183	0.007	2.246	0.050
Age → Impulsivity	-0.007	-0.079	0.008	-0.870	0.400
Socioeconomic status → Depression	0.022	0.011	0.152	0.148	>0.500
Socioeconomic status → Impulsivity	-0.502	-0.247	0.130	-3.869	<0.001
CAGE → Depression	0.079	0.080	0.052	1.527	0.200
CAGE → Impulsivity	0.076	0.077	0.075	1.024	0.400
Past history of OP poisoning → Depression	0.487	0.178	0.149	3.269	<0.001
Past history of OP poisoning → Impulsivity	-0.079	-0.029	0.201	-0.394	>0.500
OP exposure → Depression	-0.117	-0.117	0.067	-1.740	0.100
OP exposure → Impulsivity	-0.115	-0.116	0.070	-1.647	0.100
Depression → Impulsivity	-0.164	-0.164	-0.238	0.688	0.500
Impulsivity → Depression	0.371	0.371	-0.266	1.394	0.200
Depression → Suicide	0.387	0.395	0.185	2.090	0.050
Impulsivity → Suicide	0.373	0.380	0.062	6.001	<0.001

4.4.3.7 Remodelling models 1 and 3 using the severe depression subscale of the GHQ-28

The GHQ-28 and BSI questionnaire measured psychological distress or psychological wellness in the respondents of which depression is one of the domains (chapter 3, sections 3.2.1.3 and 3.2.1.4). The high number of zero counts (408, 54.3%) scored on the severe depression subscale, resulted in a limited range of values for the subscale with reduced discriminative power. Since the variability of the depression subscales was poor, all subscales of the GHQ-28 and BSI were used as measurements of depression for model 1 and 3. A potential limitation of this approach was that the measurement of depression became less accurately defined. In this section, the severe depression subscale was used to replace the four subscales of the GHQ-28 questionnaire for models A, B, I and L.

Table 4.30 summarises the goodness-of fit of the remodelled models A and I. Of the four models, models B and L did not converge. Models A2 and I2 met the criteria for "good fit" i.e. low chi-square with non-significant chi-square tests, χ^2/df less than three and RMSEA less than 0.08.

Table 4.30 Goodness-of-fit statistics of remodelled models A and I (n=447)

	Absolute fit measures					
Models	χ^2	***df***	χ^2/df	***p*-value**	**RMSEA**	**RMSEA (90% CI)**
Model 1						
A2	14.28	42	0.34	1	0	(0.0 - 0.0)
Model 3						
I2	39.33	70	0.56	0.999	0	(0.0 - 0.0)

Model estimates and path diagrams of models A2 and I2 are presented in Appendix B. Table 4.31 compares the structural path estimates of exposure and outcomes in models A and I with models A2 and I2.

Table 4.31 Structural path estimates of exposure and outcomes for variations of models A and I

Model	Path	Path coefficient		Standard error	*t*-score	*p*-value
		unstandardised	standardised			
Model 1						
A	OP exposure → Depression	0.006	0.071	0.008	0.778	0.500
A2	OP exposure → Depression	0.007	0.083	0.006	1.135	0.300
Model 3						
I	OP exposure → Depression	0.008	0.096	0.012	0.111	>0.500
	OP exposure → Impulsivity	-0.010	-0.119	0.008	-1.264	0.300
I2	OP exposure → Depression	0.017	0.194	0.009	1.812	0.100
	OP exposure → Impulsivity	-0.008	-0.089	0.007	-1.069	0.300

The path estimate between exposure and outcome of model A was not significant. Similarly when the severe depression domain replaced the four subscales of the GHQ-28 in model A2, the path estimate between exposure and outcome was not significant. In model I, there was no significant association between OP exposure and depressive symptoms (with four subscales) or OP exposure and impulsive behaviour. When the severe depression domain replaced the four subscales of the GHQ-28 in model I2, the association between OP exposure and depression became slightly stronger; however the association was not significant.

4.4.3.8 Summary of SEM models

Twelve individual measurement models were assessed as valid. Structural paths were added to the measurement models and the structural models were assessed as valid. Two models were presented for each hypothesis where OP exposure was measured by cumulative years exposed in the agriculture sector and time exposed performing any of eight farming / spraying activities, combined into one measure.

Model 1:

In model A, there was no association between OP exposure and depression in male farm workers. A risk factor associated with depression was a history of past OP poisoning. In model B, there was a negative association between OP exposure and depression in male farm workers. Additional risk factors associated with depression included a positive CAGE score and a history of past OP poisoning. Depression was positively associated with suicidal ideation.

Model 2:

In model E and F, there was no association between OP exposure and impulsivity in male farm workers. However, a risk factor associated with impulsivity was low socioeconomic score in both models. Impulsivity was positively associated with suicidal ideation.

Model 3:

It was noted that in Model H, OP exposure and depression was positively associated; with the confounders adjusted on impulsivity. Similarly in model G, OP exposure and impulsivity was negatively associated; with the confounders adjusted on depression. Models G and H were not selected as the final models for model 3, on the basis that confounders adjusting on either depression or impulsivity may not reflect the true association between OP exposure and depression and OP exposure and impulsivity. Subsequently, in the final models selected for model 3 (model I and L), there was no association between OP exposure and both depression and impulsivity in male farm workers. In model I, a risk factor associated with depression was age (older farm workers had increased risk) and a risk factor associated with impulsivity was low socioeconomic score. In model L, risk factors associated with depression were older farm workers and past history of OP poisoning and associated with impulsivity was low socioeconomic score. There was no significant association between impulsivity and depression.

The severe depression domain replaced the four subscales of the GHQ-28 questionnaire of models A, B, I and L, for a more accurate measurement of depression. Models B and L did not converge. There was no difference in the strength and the significance of the association between models A and A2. However in model I2, the association between OP exposure and depression became slightly stronger though the association was not significant.

4.5 Conclusion

This chapter presented the results of the data analysis. The proportion of respondents categorised as having of psychological distress were 18.6% on the GHQ-28 (cut-off score ≥ 24) and 22.5% on the BSI (cut-off score ≥ T_{63}).

Factor analysis of the SSI in male subsample revealed three factors with significant and non-trivial standardised factor loadings but low reliability (3-items, Cronbach's $\alpha = 0.60$). Confirmatory factor analysis revealed the three-item models to be "just-identified". The internal reliability of the original factors reported by Steer *et al* (1993) was considered reliable (3-items, Cronbach's $\alpha = 0.75$) and was subsequently used in the SEM analysis.

In addition, the following instruments were considered reliable: GHQ-28 (4-items, $\alpha = 0.72$), BSI questionnaire (9-items, $\alpha = 0.91$), BIS-11(3-items, $\alpha = 0.69$) and CAGE questionnaire (4-items, $\alpha = 0.76$).

Structural equation modelling examined three hypotheses in the development of depression, impulsivity and suicidal ideation. Twelve individual measurement models and structural models were assessed separately as valid i.e. low χ^2 with an insignificant *p*-value, χ^2/df less than three, RMSEA less than 0.08, CFI and NNFI greater than 0.90. Two models were presented for each hypothesis where, respectively, OP exposure was measured by cumulative years exposed in the agriculture sector and time exposed performing any of eight farming / spraying activities, combined into one measure.

In model 1, there was no association between OP exposure and depression in male farm workers when OP exposure was measured by cumulative years exposed. When OP exposure was measured by time exposed performing any of eight farming / spraying activities, combined into one measure, OP exposure and depression was negatively associated in male farm workers. Risk factors associated with depressive symptoms were a positive CAGE score and a past history of OP poisoning.

For model 2, there was no association between OP exposure and impulsivity in male farm workers in both variations of the OP exposure variables. A risk factor associated with impulsivity was low socioeconomic score.

For model 3, model H showed a significant positive association between OP exposure and depression and model G showed a significant negative association between OP exposure and impulsivity. However these models were not selected as the final models on the basis that confounders adjusting on either depression or impulsivity (and not depression AND impulsivity) may not reflect the true association between the exposure of OP pesticides and depression and exposure of OP pesticides and impulsivity.

In the *final* models for model 3, there was no association between OP exposure and both depression and impulsivity in male farm workers in the two variations of OP exposure. However, risk factors associated with depressive symptoms were older farm workers and a history of past OP poisoning and a risk factor associated with impulsivity was low socioeconomic score. When the depression subscale replaced the four subscales of the GHQ-28 questionnaire of models A, B, I and L, for a more accurate measurement of depression, models B and L did not converge. In model A, there was no difference in the strength and the significance of the association between models A and A2. However in model I2, the association between OP exposure and depression became slightly stronger though the association was not significant.

CHAPTER FIVE

5. Discussion and conclusion

5.1 Introduction

This thesis explored the relationship between OP pesticide exposure and the development of psychiatric outcomes in male pesticide applicators in an agricultural setting. This chapter summarises the results presented in this thesis and relates to previous research. Methodological issues and study limitations are discussed along with public health implication and recommendations for future research.

The study's main conclusions are summarised below as per research objectives.

Objective 1: To determine the validity of the instruments used to assess depressive symptoms, impulsive behaviour and suicidal ideation in the study population

The self-reported instruments measuring depression (GHQ-28: 4-items, $\alpha = 0.72$; BSI: 9-items, $\alpha = 0.91$), impulsive behaviour (BIS-11: 3-items, $\alpha = 0.69$), suicidal ideation (original SSI factors reported by Steer *et al* (1993): 3-items, $\alpha = 0.75$) and the CAGE questionnaire (4-items, $\alpha = 0.76$) were appraised as reliable as demonstrated by the Cronbach's alpha coefficients.

Objective 2: To explore the relationship between low dose OP exposure and depressive symptoms, impulsive behaviour and suicidal ideation by three causal pathways:

a) ***Model 1****: Adult farm workers exposed to low dose OP pesticides have an increased risk of depressive symptoms which in turn leads to an increased risk of suicidal ideation when compared to unexposed farm workers.*

There was no association between low dose exposure to OP pesticides and depression ($P_{DS,\ OPx} = 0.07$, $t = 0.778$, $p = 0.25$) in male farm workers when OP exposure was measured using a cumulative exposure variable. There was a negative association between OP exposure and depression ($P_{DS,\ OPx} = -0.152$, $t = -2.417$, $p = 0.01$), when OP exposure was measured by time exposed performing any of eight farming / spraying activities, combined into one measure. Risk factors associated with depression were a positive CAGE score and a history of past OP poisoning. Depression was positively associated with suicidal ideation. When the severe depression subscale replaced the four subscales of the GHQ-28 questionnaire, there was no association between OP exposure and depressive symptoms.

b) **Model 2:** *Adult farm workers exposed to low dose OP pesticides have an increased risk of impulsive behaviour, which in turn may lead to an increased risk of suicidal ideation when compared to unexposed farm workers.*

There was no association between long term exposure to OP pesticides and impulsivity in male farm workers in both models (model E: $P_{IB, OPx}$ = -0.107, t=-1.591, p=0.10; model F: $P_{IB, OPx}$ =-0.097, t=-1.757, p=0.10). A risk factor associated with impulsivity was low socioeconomic score. Impulsivity was positively associated with suicidal ideation.

c) **Model 3:** *Adult farm workers exposed to low dose OP pesticides have BOTH an increased risk of depressive symptoms and an increased level of impulsive behaviour compared to unexposed farm workers. Given above, there may be an interaction between depressive symptoms and impulsive behaviour which modifies the risk for suicide in adult farm workers exposed to low dose OP pesticides when compared to unexposed farm workers.*

In Model H, OP exposure and depression were positively associated ($P_{DS, OPx}$ = 0.212, t = 2.972, p = 0.01). In model G, OP exposure and impulsivity was negatively associated ($P_{IB, OPx}$ = -0.323, t = -3.107, p = 0.01). The relationship between OP exposure and depression or OP exposure and impulsivity for models G and H became significant based on which construct the confounders were adjusted on. However, models I and L were selected for the final model 3, on the basis that the confounders were adjusted on <u>both</u> depression and impulsivity and would therefore reflect a more accurate association.

In models I and L, there was no association found between long term exposure to OP pesticide and BOTH depression and impulsive behaviour in male farm workers (model I: $P_{DS, OPx}$ = -0.096, t = 0.111, p > 0.50, $P_{IB, OPx}$ = -0.119, t = -1.264, p = 0.30; model L: $P_{DS, OPx}$ = 0.117, t = -1.740, p = 0.10, $P_{IB, OPx}$ = -0.116, t = -1.647, p = 0.10). Risk factors associated with both depressive symptoms and impulsive behaviour were age (older male farm workers had increased risk), a history of past OP poisoning and low socioeconomic score. There was no significant association between depression and impulsivity. When the severe depression subscale replaced the four subscales of the GHQ-28 questionnaire, the association between OP exposure and depression became stronger; however it was not significant.

5.2 Validity of the instruments

This study represents the first in South Africa to address the validity of the GHQ-28, BIS-11, BSI, and SSI in farm worker populations. For the measurement of psychological symptoms in farm workers, the GHQ-28 (4-items, Cronbach's alpha (α) = 0.72) and the BSI questionnaires (9-items, Cronbach's alpha (α) = 0.91) were considered reliable. The internal reliability of the GHQ-28 questionnaire was lower than the 0.82 to 0.86 range reviewed by Goldberg and Williams (1988). However, the BSI questionnaire exceeded the range reported by Derogatis and Meliseratos (1983) where the internal consistency of the nine BSI subscales ranged from 0.71 to 0.85 in a sample of 1002 psychiatric outpatients. The BIS-11 measuring impulsivity was considered reliable (3-items, Cronbach's alpha (α) = 0.69). However, the internal reliability was lower than the range of 0.79 to 0.83 reported for undergraduate students, substance abuse patients, psychiatric inpatients and male inmates at a maximum security prison derived by Patton *et al* (1995).

Factor analysis of the SSI derived three items by principal-component analysis with varimax rotation. The summated scale was not considered reliable (3-items, $\alpha = 0.60$). The originally reported factors by Steer *et al* (1993) yielded an internal reliability estimate of 0.75. Though this estimate was slightly lower than the Cronbach's alpha coefficient of 0.89 found by Beck *et al* (1979) in a group of 90 psychiatric inpatients, it was considered a reliable instrument to measure suicidal ideation in the study population.

The CAGE questionnaire had an adequate internal reliability (4-items, $\alpha = 0.76$). A review by Dhalla and Kopec (2007) revealed high test-retest reliability of the CAGE questionnaire (0.85 to 0.95).

5.3 Mental health outcomes

Approximately 20% of the study population was categorised as having symptoms of psychological distress. The South African Stress and Health (SASH) study conducted as part of the World Health Organisation World Mental Health (WMH) Survey Initiative reported the Western Cape Province to have had the highest 12-month and lifetime prevalence rates for any common mental disorders across the nine provinces (Herman *et al*, 2009).

Female farm workers reported higher levels of psychological symptoms than male farm workers. This finding was consistent with Stallones and Besseler (2002) where depression among female farm workers were 2.67 times more likely than male farm workers in a study conducted by in Colorado using the Centre for Epidemiologic Studies – depression (CES-D) scale. This finding was also consistent with Tomlinson *et al* (2009) where South African women in the general population was 1.75 times more likely to experience lifetime depression than men and 2.17 times more likely to experience 12-month major depression episode than men.

Female farm workers reported higher levels of suicidal ideation than male farm workers. This is consistent with findings by Joe *et al* (2008) where women reported twice as many suicide attempts as men (3.8% (se=0.5) *v.* 1.8% (se=0.3). In addition, racial group differences revealed that Coloured populations reported the highest level of impulsive suicide attempts (Joe *et al*, 2008). Results from the SASH study where suicidality was assessed by a section of the WHO Composite International Diagnostic Interview version 3.0, the authors reported an estimated lifetime prevalence suicide ideation rates of 9.1% and suicide attempts rates of 2.9% (Joe *et al*, 2008).

Moeller *et al* (2001) have defined impulsivity, on the basis of a biopsyochosocial approach, as "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individual or to others". Further, impulsivity have been linked to several psychiatric disorders including antisocial and borderline personality disorder, substance abuse, bipolar disorder and attention deficit hyperactivity disorder. The principal component factor analysis of the BIS reported by Patton *et al* (1995) suggested a three factor model of impulsivity that where respondents were described as having greater motor activation, less attention and less planning.

5.4 OP pesticide exposure

OP pesticide exposure was measured by an occupational and environmental health questionnaire that utilised an approach based on a job-exposure matrix (JEM) applied in past occupational health studies amongst South African farm workers (London *et al*, 1998). In the primary analysis reported by Major (2010), concerns regarding the validity of the JEM data were highlighted. These included observer error of the interviewers on data collected on the frequency of pesticide application. Due to poor data quality, a cumulative exposure variable based on a complete JEM could not be calculated. A further concern regarding the interviewers not understanding the lay terms of the names of the pesticides used by the farm workers, may have inadvertently resulted in non-differential misclassification in that pesticides other than OP may have been included in the analysis.

Overall, male farm workers were exposed to OP pesticides for longer duration compared to female farm workers. In addition, male farm workers were involved in more pesticide applicator activities e.g. spraying from the back of a tractor, spraying pesticides from a back pack and dipping livestock when compared to female farm workers who were primarily employed for general farm work. Workers who handle pesticides are considered to be at a higher risk of exposure than workers who do not handle pesticides directly (Jaga and Dharmani, 2003). Though this should have implied a higher risk for males, female farm workers reported higher levels of psychological symptoms and suicidal ideation as supported by the literature (Herman *et al*, 2008; Stallone and Beseler, 2002; Joe *et al*, 2008; Tomlinson, 2008).

5.5 The association between OP pesticide exposure and mental health outcomes

Three hypotheses were examined as possible causal models for the development of depressive symptoms, impulsive behaviour and suicidal ideation due to chronic low dose OP pesticide exposure in the agricultural sector. A primary analysis conducted by Major (2010) using logistic regression revealed no evidence of a positive association between cumulative and current OP pesticide exposure and neuropsychiatric effects on this population of grape farm workers.

The benefit of using a structural equation modelling approach compared to multiple regression was the use of confirmatory factor analysis to reduce measurement error by having multiple indicators per latent variable, the functionality of testing models overall rather than coefficients individually including the ability to test models with multiple dependents (Hair *et al*, 2010; Kline, 2005). Despite the application of a more rigorous analysis than multiple regression analysis, no positive association was found between OP exposure and depression; with the exception of model H (model 3) where the confounding factors were adjusted on impulsivity. Model H was not selected as the final model as confounders adjusted on both impulsivity and depression would have reflected a more accurate relationship between OP exposure and the constructs. The absence of an association could be explained by the lack of specificity when measuring depression by using all of the subscales of the GHQ-28 rather than the severe depression subscale. However, when the depression subscale was applied in the specific models, the narrow range of the data for depression subscale meant a limited gradient was available so may have resulted in failure to demonstrate association between exposure and depressive symptoms. The lack of an association is in keeping with previous findings by Solomon *et al* (2007) where no association was found between handling of sheep dip and anxiety and depression.

A negative association was found between OP pesticide exposure and depression (four subscales of GHQ-28 questionnaires) in male workers when OP exposure was measured using a combination of 8 farming / spraying activities. The negative association could be explained by a variation of the *healthy worker effect* where farm workers with mental health impairment were less likely to be employed as pesticide applicators and more likely to be placed as general farm workers.

5.6 Risk factors for the development of mental health outcomes

Although the study hypothesis was not supported in the main analysis, risk factors were identified as possible targets to improve the plight of farm workers.

5.6.1 Alcohol-related problems

Over half (56.4%) of the study participants admitted to current use of alcohol and 77% of the remaining participants admitted to having used alcohol in the past. South Africa is known to have one of the highest alcohol consumptions in the world per head for all individuals who drink alcohol (Rehm *et al*, 2007). The lifetime prevalence of alcohol abuse and alcohol dependence in South Africa was 11.4% and 2.6% respectively (Stein *et al*, 2008). Alcohol consumption in Western Cape farming communities has been linked with the historical practice of paying farm workers in part with alcohol known as the DOP system (Scully, 1992). This practice has shown to be in existence in the Western Cape until well into the 1990's (London, 2000).

In the study population, 88.3% of the respondents were categorised as having alcohol-related problems and would have warranted referral for clinical intervention. This finding is almost identical to an earlier study by London *et al* (1998) where 87% of the farm workers in the Western Cape reported alcohol-related problems (CAGE score ≥ 2). In a more recent study by Ojo *et al* (2010), 46% of women in the Western Cape were found to be current drinkers compared to 27% of women living in Gauteng Province. This finding was higher than the 30.2% of female farm workers who reported current use of alcohol. In addition, a larger proportion of male farm workers (61.5% vs. 38.5%) reported alcohol-related problems than female farm workers. This is in keeping with 3.64% of 12-month alcohol use disorders prevalence estimates reported in South African males compared to 0.88% in females (WHO, 2011).

A positive CAGE score was found to be positively associated with the somatisation subscale in farm workers. Excessive alcohol use has been associated with damage to the structure and function of the brain and impairment of cognition and behaviour (Greene, 2010). Neuropsychological effects associated with alcohol misuse range from the more severe impairments associated with Wernike's Korsakoff Syndrome and the global deterioration characteristic of alcohol related dementia to the milder pattern of deficits observed on traditional cognitive tasks (Greene *et al*, 2010).

5.6.2 History of OP pesticide poisoning

14.2% of farm workers experienced a past episode of OP pesticide poisoning. Farm workers with a history of past pesticide poisoning reported higher levels of somatic, anxiety and insomnia and social dysfunction symptoms than farm workers without a history of past pesticide poisoning. This was in keeping with findings by Kamel and Hoppin (2004) and Kamel *et al* (2005), where a history of pesticide poisoning was associated with increased neuropsychiatric symptoms among male licensed private pesticide applicators in Agricultural Health Study. In addition, Wesseling *et al* (2010) found that banana farm workers in Costa Rica with past OP poisoning had increased symptoms of psychological distress as measured by the BSI questionnaire, than farm workers with no past poisoning. This finding is also consistent with previous observations by London *et al* (1998) where 11% of respondents reported previous poisoning.

5.6.3 Lower socioeconomic score

Higher levels of impulsive behaviour were reported by male farm workers with a low socioeconomic score i.e. ownership of less than four commodities. Common mental disorders are known to be twice as frequent among the poor as among the rich (Patel, 2001). In addition, in Santiago, Chile common mental illness was found more among people living in poor and overcrowded conditions (Araya *et al*, 2003).

In the SASH study, respondents with a low-average income have been associated with a *lower* risk of common mental disorders compared to individuals with high incomes (Herman *et al*, 2008). However, Patel *et al* (2008) have proposed an increase in psychiatric disorders in South Africa with the rise in the prevalence of social risk factors such as poverty, conflict and displacement. Though no association was found between socioeconomic score and suicidal ideation in this study, Zhang *et al* (2009) showed a two-fold increased odds of suicidal ideation in a coastal province of China in respondents with a lower annual per capita income.

5.6.4 Older age

Older male farm workers reported higher levels of psychological symptoms. This is consistent with SASH study findings by Herman *et al* (2008), where South African respondents aged between 35 to 49 years had two-fold risk of developing common mental illness and the severity of the disorders were found to be higher among respondents aged 50 to 64 years. In addition, the risk of developing a major depressive episode was significantly higher among respondents between the ages of 40 and 49 years, who were 1.7 times more likely to have experienced lifetime major depressive episode than other age group.

5.7 Limitations

The following study limitations are discussed:

a) The study design was cross-sectional and the temporal order between exposure and the mental health outcomes could not be ascertained. Therefore causality could not be inferred.

b) Self-reporting questionnaires were used to measure the mental health outcomes. A known limitation of self-report techniques is recall bias and may include a possible response bias where participants provide responses that is considered socially desirable. However, the validity of the questionnaires were tested and found to be reliable.

c) Generalisability of the results was affected in two ways: although intended as a purely random sample, convenience sampling entered into the recruitment process as access to farm workers was limited. Therefore the sample may not have been representative of the entire farm working population. Secondly, due to the exclusion of female farm workers from the multivariate analysis, the associations between OP exposure and mental health outcomes could only be inferred towards the male farm workers.

d) The narrow range of results for the depression subscales of the GHQ-28 and BSI questionnaires may have added to the lack of an association due to its reduced power.

e) Concerns regarding the quality of data were discussed in section 5.4. Exposure misclassification may have had the potential to increase random error if the misclassification was non-differentially distributed. This may have diluted an association between OP exposure and mental health outcomes, where exposure of the respondents were randomly under or over estimated and could explain the lack of association demonstrated.

f) The language preference among Western Cape farm workers was Afrikaans. Concerns regarding the interpretation of translated version of the SSI to Afrikaans resulted in a lower reliability estimate (3-items, $\alpha = 0.60$) than other instruments.

g) A variation of the healthy worker effect could explain the lack of association between male farm workers and mental health outcomes, where farm workers with mental impairment are less likely to be assigned as pesticide applicators.

h) The sample size may not have been adequate for the increased complexity of model 3 of the SEM models. The initial sample size (n=752) was adequate i.e. 14 respondents per free parameter set. However when female farm workers were excluded, the number of respondents was reduced to 6 to 8 respondents per free parameter estimated for model 3 which was less than the recommended guideline of 10 respondents per free parameter set guideline (Hoe, 2008). This may have contributed towards the lack of association reported for model 3.

5.8 Public health implications

OP pesticide poisoning is a major public health issue globally in the agricultural sector. Approximately 20% of respondents reported psychological distress as screened by the GHQ-28 and BSI. As screening tools of mental ill-health, these respondents would have required further mental health assessment. This raises the concern regarding farm workers who may be at high risk of having developed a mental illness and may not be adequately identified and be referred to mental health care services.

The prevalence of alcohol-related problems was high (88.3%) in the study community. Alcohol misuse has been identified as a major factor underlying homicide, intimate partner violence, rape, abuse of children and other unintentional injuries in South Africa (Seedat *et al*, 2009). In addition, this may have further implications for the families of exposed farm workers, such as FAS in drinking mothers (Morojele *et al*, 2010). Poverty and mental health are closely linked and studies have suggested that poverty increases the risk of mental disorders and having a mental disorder increases the likelihood of descending into poverty (Patel, 2001). The combined effect of the prevalence alcohol-related problems and poverty of farm workers raises a barrier to maintaining a stable mental health in farm workers.

Eddleston and Phillips (2002) proposed that deaths related to pesticides may be due to the ease of access to highly toxic pesticides. The authors state that the deaths related to suicidal behaviour may not necessarily be due to wanting to commit suicide, however the ingestion of a highly toxic pesticide often results in death. Internationally, the World Health Organization (WHO) has established a program that promotes and coordinates policies, strategies, and guidelines for the use of pesticides in public health, including in the areas of pesticide specifications, safety issues, and effectiveness (FAO/WHO, 2008). The World Health Organisation has recommended community intervention strategies to prevent unintentional and intentional deaths from suicide by pesticides through education and safe storage of pesticides (WHO, 2006).

5.9 Recommendations

The following recommendations are proposed to decrease further pesticide-related mental health illness and deaths in the agricultural sector.

a) It is recommended that mental health care services become integrated into primary health care services in the farming districts. This would entail training of primary health care nurses to recognise and appropriately refer farm workers with mental health disorders. In addition this would facilitate early identification of farm workers at risk and appropriate reallocation of duties that are considered to be of lower risk e.g. general farm work.

b) Screening for alcohol misuse or dependence should be incorporated in the primary health care approach thereby facilitating early recognition of alcohol-related problems. It is essential that efforts are targeted towards education of farm workers and their families regarding the dangers of alcohol misuse especially in pregnancy. Farm workers should be able to access programmes that assist in the management of alcohol and drug addiction. Considerable distances between the farms and clinics and high transport costs are common deterrents to access of health care services. This could be addressed by engaging the employer to establish weekly or bi-weekly trips to clinics to enable the farm workers access to care.

c) It is incumbent upon the employer to establish education and training programmes on the safe practices of handling pesticides on farms. This should be aimed in the language and at the education level of the farm worker in the Western Cape, where a high level of illiteracy has been found (London *et al*, 1998). The program should incorporate practices that may reduce occupational risk i.e. proper supervision of pesticide application activities, proper storage of pesticides, proper pesticide container disposal, the use of personal protective equipment, personal hygiene and food handling practices (Jaga and Dhamani, 2002).

d) Restrictions regarding access to pesticides could be implemented where storage of pesticides is maintained outside of the household and therefore away from direct access during times of stress. In our study, 50.7% of respondents reported increased impulsive behaviour. This may prevent future suicidal attempts (Phillips and Eddleston, 2002).

e) It is crucial that a surveillance program be established to monitor and assess farm worker exposure to OP pesticides by measuring cholinesterase activity in red blood cells and serum. This would facilitate biological and clinical monitoring (upon referral) for early recognition of pesticide poisoning, removal of the farm worker from the exposure and subsequent early treatment of pesticide poisoning.

f) Acute pesticide poisoning is a notifiable condition. It is recommended that patients brought in to hospital or primary health care services diagnosed with acute pesticides poisoning be monitored for any early signs of mental ill-health.

5.10 Future Research

To our knowledge, this is the first study validating the GHQ-28, BSI, BIS-11 and SSI questionnaires in South African farming communities. In addition, this is the first study where a SEM approach was applied looking at the association between OP pesticide exposure and suicide in the South African agricultural setting. However future research is suggested in the following areas:

a) Female farm workers, in South Africa, have been identified as being at higher risk of developing depression and suicidal ideation. Their OP pesticide exposure profile is different from that to male farm workers. Additional research is warranted to fully explore the risk behaviour and health care seeking practices of female workers in the development of mental illness.

b) An additional vulnerable group that have often been overlooked are the children of farm workers. Limited research has been undertaken in the health and behavioural effects of pesticides in South African children. With the high prevalence of alcohol-related problems in the study population, future longitudinal research is suggested where a South African birth cohort of farm worker children is established and followed through time to examine their risk of developing neurological, learning disorders, mental illness and behavioural outcomes.

c) Future occupational observational studies should try to incorporate a longitudinal study design as causal inferences between pesticide exposure and mental health outcomes could then be made.

d) Identification of vulnerable farm workers and improved determination of individuals at risk may be achieved by future studies focusing on biomarkers that may be able to assess exposure and biological effects such as DNA damage and oxidative stress, and techniques that measure genetic susceptibility.

5.11 Conclusion

This study was aimed at bridging the gap in knowledge by examining the association between chronic exposure to low-dose OP pesticides and its association with depression, impulsivity and suicide among farm workers. To accomplish this, four questionnaires were tested for their validity in a South African farm worker study population. Three hypotheses were tested by means of structural equation modelling approach.

Approximately twenty percent of the study population were categorised as having psychological symptoms (18.6% on the GHQ-28 (cut-off score $\geq$ 24) and 22.5% on the BSI (cut-off score $\geq T_{63}$). Median cut-offs on the BIS-11 and SSI categorised 50.7% (median BIS-11 cut-off score $\geq$ 54) of the respondents as having impulsive behaviour and 50.5% (median SSI cut-off score $\geq$ 1) as having suicidal ideation.

Factor analysis of the SSI in male subsample revealed three factors with significant and non-trivial standardised factor loadings but low reliability. The original factors reported by Steer *et al* (1993) had an internal reliability of 0.75 that was considered to be "adequate". In addition, the self-reported instruments measuring psychological symptoms of distress (GHQ-28: 4-items, α = 0.72; BSI: 9-items, α = 0.91), impulsivity (BIS-11: 3-items, α = 0.69), and the CAGE questionnaire (4-items, α = 0.76) were considered to be reliable.

Structural equation modelling examined three hypotheses in the development of depression, impulsive behaviour and suicidal ideation. Twelve individual measurement models and structural models were assessed separately as valid i.e. low χ^2 with an insignificant *p*-value, χ^2/df less than three, RMSEA less than 0.08, CFI and NNFI greater than 0.90. Two models were presented for each hypothesis where, respectively, OP exposure was measured by cumulative years exposed in the agriculture sector and when OP exposure was measured by time exposed performing any of eight farming / spraying activities, combined into one measure.

In model 1, there was no association between OP exposure and depression in male farm workers when OP exposure was measured by cumulative years exposed. When OP exposure was measured by time exposed performing any of eight farming / spraying activities, combined into one measure there was a negative association between OP exposure and depression in male farm workers. Additional risk factors associated with depression were a positive CAGE score and a history of past OP poisoning. Depression was positively associated with suicidal ideation.

For model 2, there was no association between OP exposure and impulsivity in male farm workers in both variations of the OP exposure variables. A risk factor associated with impulsivity was low socioeconomic score. Impulsivity was positively associated with suicidal ideation.

In the final models selected for model 3, there was no association between OP exposure and both depression and impulsivity in male farm workers in the two variations of OP exposure. However, risk factors for depression were age (being older increased risk) and a history of past OP poisoning. A risk factor associated with impulsivity was low socioeconomic score. There was no significant interaction between depressive symptoms and impulsive behaviour.

The negative association found between chronic low dose OP exposure and depression may be explained by a variation of the healthy worker effect where farm workers with mental illness would be less likely to be assigned to pesticide applicator duties. Exposure misclassification may have contributed towards the lack of an association between OP exposure and the mental health outcomes. The generalisability of the results was affected by intrusion of convenience sampling and the restriction to the male subsample for the SEM analysis.

This thesis represents the first validation of the SSI questionnaire in a South African population. Further, the study highlights the high proportion of farm workers categorised with psychological symptoms that may be potentially attributable to following risk factors: a history of past OP poisoning, older age, a positive CAGE score and low socioeconomic score. These findings emphasises the need for improved surveillance and earlier recognition of mental health conditions prevalent amongst similar agricultural populations.

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7. Appendix A

Table 7.1 Model estimates of model A

Path	**Path coefficient**		**Standard error**	***t*-score**	***p*-value**
	unstandardised	**standardised**			
Measurement model estimates					
Cage 1 → CAGE	0.308	0.750	-0.028	11.176	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.410	<0.001
Cage 3 → CAGE	0.373	0.842	-0.018	21.014	<0.001
Cage 4 → CAGE	0.243	0.495	-0.021	11.684	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.486	0.737	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.175	0.850	-0.212	14.973	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.603	0.341	-0.178	3.384	<0.001
GHQ subscale D (Severe depression) → Depression	1.598	0.576	-0.272	5.869	<0.001
SI subscale A (Desire for death) → Suicide	0.529	0.710	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.479	0.576	-0.131	3.648	<0.001
SI subscale C (Active suicide desire) → Suicide	0.496	0.855	-0.036	13.706	<0.001
Structural model estimates					
Age → Depression	0.001	0.001	0.008	0.013	>0.500
Socioeconomic status → Depression	-0.232	-0.113	0.127	-1.833	0.100
CAGE → Depression	0.085	0.085	0.051	1.669	0.100
Past history of OP poisoning → Depression	0.401	0.146	0.144	2.786	0.050
OP exposure → Depression	0.006	0.071	0.008	0.778	0.500
Depression → Suicide	0.478	0.478	-0.221	2.162	0.050

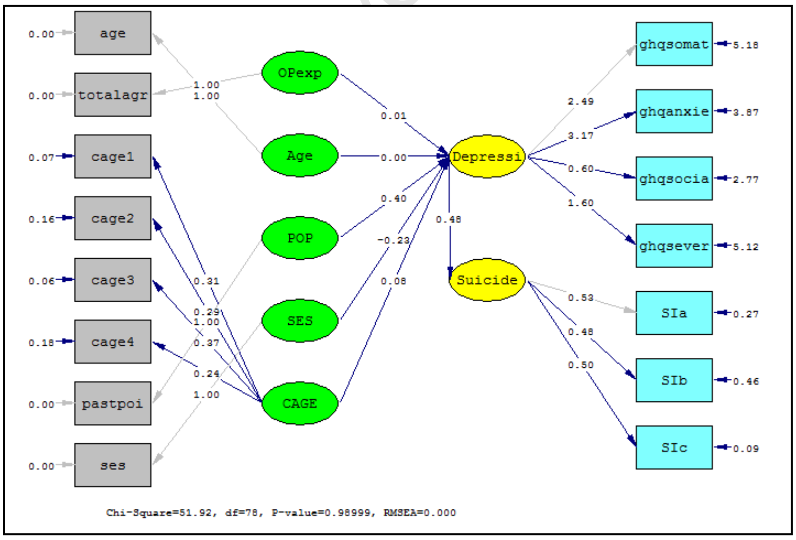

Figure 7.1 Model A

Table 7.2 Model estimates of model B

Path	Path coefficient		standard error	*t*-score	p-value
	Unstandardised	standardised			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.383	0.520	-0.701	6.527	<0.001
Hand spraying pesticides → OP exposure	5.623	0.622	-0.838	6.707	<0.001
Spraying pesticides using a backpack → OP exposure	3.920	0.488	-0.748	5.243	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.253	<0.001
Harvesting → OP exposure	9.220	0.964	-0.529	17.444	<0.001
Gardening → OP exposure	4.849	0.565	-0.834	5.882	<0.001
Dipping livestock → OP exposure	1.900	0.331	-0.600	3.169	0.010
Orchards → OP exposure	7.403	0.795	-0.657	11.270	<0.001
Cage 1 → CAGE	0.308	0.750	-0.028	11.180	<0.001
Cage 2 → CAGE	0.288	0.586	-0.023	12.278	<0.001
Cage 3 → CAGE	0.374	0.843	-0.018	20.903	<0.001
Cage 4 → CAGE	0.242	0.493	-0.021	11.625	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.494	0.739	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.185	0.853	-0.210	15.141	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.598	0.338	-0.177	3.382	<0.001
GHQ subscale D (Severe depression) → Depression	1.568	0.572	-0.270	5.871	<0.001
SI subscale A (Desire for death) → Suicide	0.530	0.711	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.479	0.577	-0.131	3.648	<0.001
SI subscale C (Active suicide desire) → Suicide	0.496	0.855	-0.036	3.648	<0.001
Structural model estimates					
Age → Depression	0.012	0.139	0.007	1.867	0.100
Socioeconomic status → Depression	-0.174	-0.085	0.130	-1.338	0.200
CAGE → Depression	0.103	0.103	0.052	1.982	0.050
Past history of OP poisoning → Depression	0.424	0.154	0.153	2.770	0.010
OP exposure → Depression	-0.152	-0.152	0.063	-2.417	0.010
Depression → Suicide	0.474	0.474	-0.219	2.159	0.050

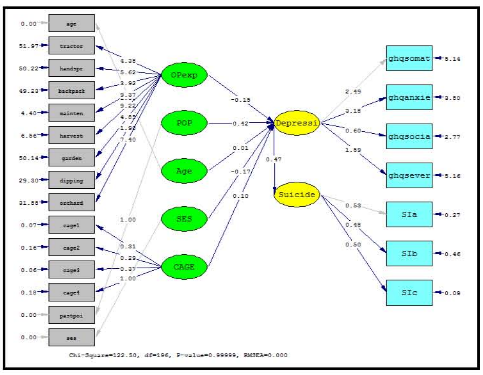

Figure 7.2 Model B

Table 7.3 Model estimates of model C

Path	Path coefficient		standard error	*t*-score	p-value
	unstandardised	standardised			
Measurement model estimates					
Cage 1 → CAGE	0.309	0.752	-0.027	11.345	<0.001
Cage 2 → CAGE	0.289	0.588	-0.023	12.505	<0.001
Cage 3 → CAGE	0.372	0.840	-0.018	20.757	<0.001
Cage 4 → CAGE	0.243	0.495	-0.021	11.649	<0.001
BSI subscale A (Somatisation) → Depression	2.376	0.688	_	_	_
BSI subscale B (Obsessive-compulsive behaviour) → Depression	2.511	0.777	-0.216	11.598	<0.001
BSI subscale C (Interpersonal sensitivity) → Depression	1.879	0.756	-0.179	10.514	<0.001
BSI subscale D (Depression) → Depression	1.745	0.750	-0.205	8.515	<0.001
BSI subscale E (Anxiety) → Depression	2.143	0.766	-0.226	9.474	<0.001
BSI subscale F (Hostility) → Depression	1.945	0.671	-0.201	9.676	<0.001
BSI subscale G (Phobic Anxiety) → Depression	1.853	0.704	-0.260	8.950	<0.001
BSI subscale H (Paranoid ideation) → Depression	2.219	0.651	-0.154	8.541	<0.001
BSI subscale I (Psychotism) → Depression	1.603	0.708	-0.154	10.400	<0.001
SI subscale A (Desire for death) → Suicide	0.517	0.693	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.477	0.575	-0.124	3.857	<0.001
SI subscale C (Active suicide desire) → Suicide	0.506	0.872	-0.045	11.311	<0.001
Structural model estimates					
Age → Depression	-0.004	-0.042	0.008	-0.466	>0.500
Socioeconomic status → Depression	-0.264	-0.129	0.116	-2.272	0.050
CAGE → Depression	0.104	0.104	0.061	1.693	0.010
Past history of OP poisoning → Depression	0.182	0.066	0.167	1.086	0.300
OP exposure → Depression	0.001	0.011	0.008	0.121	>0.500
Depression → Suicide	0.502	0.502	-0.198	2.538	0.050

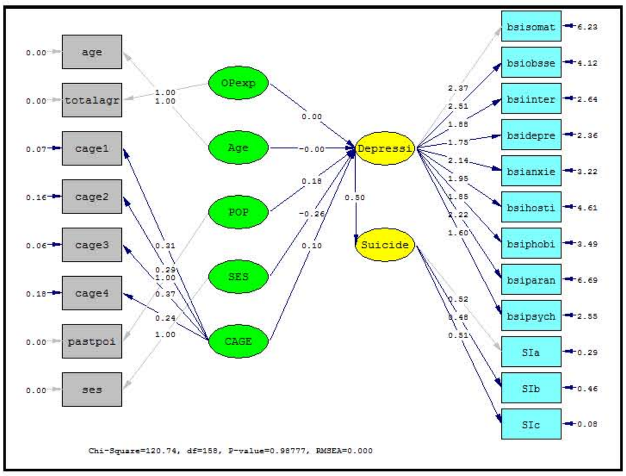

Figure 7.3 Model C

Table 7.4 Model estimates of model D

Path	Path coefficient		standard error	*t*-score	p-value
	unstandardised	standardised			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.385	0.520	-0.701	6.260	<0.001
Hand spraying pesticides → OP exposure	5.626	0.622	-0.838	6.711	<0.001
Spraying pesticides using a backpack → OP exposure	3.922	0.488	-0.748	5.245	<0.001
Maintenance work → OP exposure	9.365	0.976	-0.486	19.254	<0.001
Harvesting → OP exposure	9.221	0.964	-0.528	17.470	<0.001
Gardening → OP exposure	4.849	0.564	-0.834	5.815	<0.001
Dipping livestock → OP exposure	1.889	0.331	-0.599	3.170	0.010
Orchards → OP exposure	7.404	0.795	-0.657	11.278	<0.001
Cage 1 → CAGE	0.309	0.752	-0.027	11.369	<0.001
Cage 2 → CAGE	0.289	0.587	-0.023	12.386	<0.001
Cage 3 → CAGE	0.372	0.840	-0.018	20.635	<0.001
Cage 4 → CAGE	0.242	0.493	-0.021	11.586	<0.001
BSI subscale A (Somatisation) → Depression	2.370	0.689	–	–	–
BSI subscale B (Obsessive-compulsive behaviour) → Depression	2.508	0.777	-0.216	11.593	<0.001
BSI subscale C (Interpersonal sensitivity) → Depression	1.878	0.756	-0.179	10.499	<0.001
BSI subscale D (Depression) → Depression	1.744	0.749	-0.205	8.965	<0.001
BSI subscale E (Anxiety) → Depression	2.143	0.766	-0.277	9.455	<0.001
BSI subscale F (Hostility) → Depression	1.946	0.671	-0.201	9.675	<0.001
BSI subscale G (Phobic Anxiety) → Depression	1.845	0.704	-0.207	8.965	<0.001
BSI subscale H (Paranoid ideation) → Depression	2.221	0.651	-0.260	8.542	<0.001
BSI subscale I (Psychotism) → Depression	1.603	0.708	-0.154	10.420	<0.001
SI subscale A (Desire for death) → Suicide	0.517	0.694	–	–	–
SI subscale B (Preparation for suicide) → Suicide	0.478	0.575	-0.124	3.857	<0.001
SI subscale C (Active suicide desire) → Suicide	0.505	0.872	-0.045	11.340	<0.001
Structural model estimates					
Age → Depression	0.002	0.114	0.006	0.316	>0.500
Socioeconomic status → Depression	-0.235	-0.115	0.121	-1.940	0.100
CAGE → Depression	0.113	0.022	0.063	1.812	0.100
Past history of OP poisoning → Depression	0.194	0.071	0.170	1.143	0.300
OP exposure → Depression	-0.102	-0.102	0.074	-1.372	0.200
Depression → Suicide	0.502	0.502	-0.198	2.539	0.050

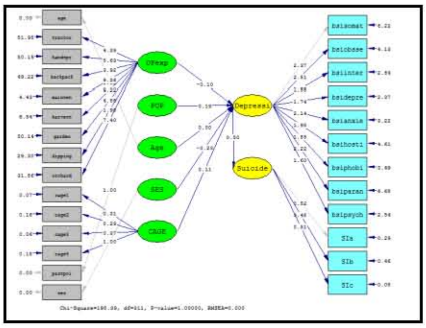

Figure 7.4 Model D

Table 7.5 Model estimates of model E

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Cage 1 → CAGE	0.308	0.751	-0.027	11.267	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.499	<0.001
Cage 3 → CAGE	0.373	0.843	-0.018	21.060	<0.001
Cage 4 → CAGE	0.242	0.492	-0.021	11.593	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.927	0.580	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.395	0.563	-0.278	8.601	<0.001
BIS subscale C (Non-planning impulsiveness) → Impulsivity	4.272	0.832	-0.476	8.983	<0.001
SI subscale A (Desire for death) → Suicide	0.567	0.761	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.485	0.584	-0.141	3.449	<0.001
SI subscale C (Active suicide desire) → Suicide	0.463	0.798	-0.049	9.475	<0.001
Structural model estimates					
Age → Impulsivity	-0.006	-0.066	0.007	-0.834	0.500
Socioeconomic status →Impulsivity	-0.481	-0.235	0.127	-3.783	<0.001
CAGE → Impulsivity	0.064	0.064	0.065	0.976	0.400
Past history of OP poisoning → Impulsivity	-0.129	-0.047	0.140	-0.919	0.400
OP exposure → Impulsivity	-0.009	-0.107	0.006	-1.591	0.200
Impulsivity → Suicide	0.465	0.465	-0.100	4.661	<0.001

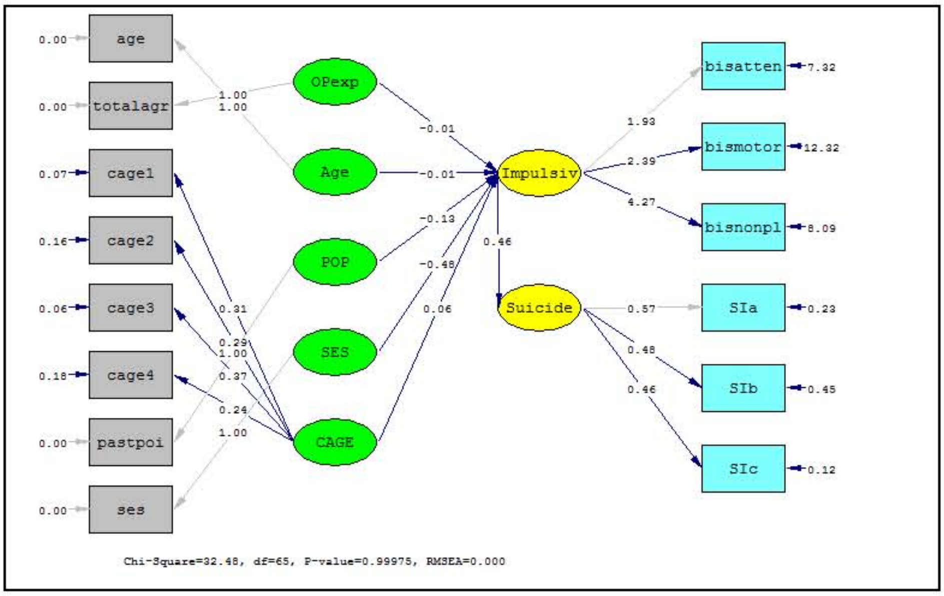

Figure 7.5 Model E

Table 7.6 Model estimates of model F

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.384	0.520	-0.700	6.259	<0.001
Hand spraying pesticides → OP exposure	5.626	0.622	-0.838	6.712	<0.001
Spraying pesticides using a backpack → OP exposure	3.921	0.488	-0.748	5.245	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.266	<0.001
Harvesting → OP exposure	9.219	0.963	-0.528	17.447	<0.001
Gardening → OP exposure	4.849	0.565	-0.834	5.817	<0.001
Dipping livestock → OP exposure	1.899	0.331	-0.599	3.170	0.010
Orchards → OP exposure	7.404	0.795	-0.656	11.280	<0.001
Cage 1 → CAGE	0.308	0.751	-0.027	11.274	<0.001
Cage 2 → CAGE	0.288	0.586	-0.023	12.368	<0.001
Cage 3 → CAGE	0.374	0.844	-0.018	20.943	<0.001
Cage 4 → CAGE	0.241	0.491	-0.021	11.531	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.929	0.580	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.396	0.563	-0.278	8.609	<0.001
BIS subscale C (Non-planning impulsiveness) → Impulsivity	4.264	0.831	-0.469	9.094	<0.001
SI subscale A (Desire for death) → Suicide	0.567	0.762	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.485	0.584	-0.141	3.445	<0.001
SI subscale C (Active suicide desire) → Suicide	0.462	0.797	-0.049	9.402	<0.001
Structural model estimates					
Age → Impulsivity	-0.008	-0.093	0.007	-1.244	0.300
Socioeconomic status →Impulsivity	-0.481	-0.235	0.131	-3.683	<0.001
CAGE → Impulsivity	0.063	0.063	0.065	0.973	0.400
Past history of OP poisoning → Impulsivity	-0.124	-0.045	0.140	-0.886	0.500
OP exposure → Impulsivity	-0.097	-0.097	0.055	-1.757	0.100
Impulsivity → Suicide	0.467	0.467	-0.100	4.671	<0.001

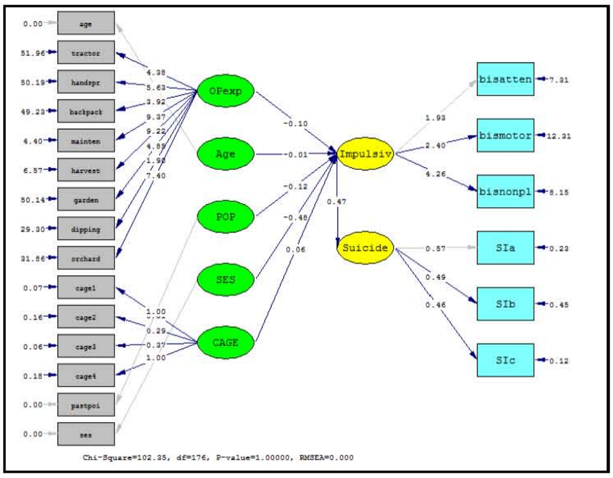

Figure 7.6 Model F

Table 7.7 Model estimates of model G

Path	Path coefficient unstandardised	Path coefficient standardised	standard error	*t*-score	*p*-value
Measurement model estimates					
Cage 1 → CAGE	0.308	0.751	-0.027	11.273	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.510	<0.001
Cage 3 → CAGE	0.373	0.842	-0.018	21.007	<0.001
Cage 4 → CAGE	0.242	0.492	-0.021	11.576	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.467	0.731	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.176	0.850	-0.209	15.208	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.608	0.343	-0.178	3.406	<0.001
GHQ subscale D (Severe depression) → Depression	1.612	0.581	-0.273	5.900	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.936	0.583	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.401	0.565	-0.282	8.522	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.250	0.828	-0.467	9.106	<0.001
SI subscale A (Desire for death) → Suicide	0.554	0.743	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.489	0.589	-0.140	3.490	<0.001
SI subscale C (Active suicide desire) → Suicide	0.472	0.814	-0.046	10.259	<0.001
Structural model estimates					
Age → Depression	-0.012	-0.131	0.019	-0.593	>0.500
Socioeconomic status → Depression	-1.202	-0.587	0.574	-2.095	<0.001
CAGE → Depression	0.218	0.218	0.192	1.135	0.300
Past history of OP poisoning → Depression	0.161	0.059	0.574	0.450	>0.500
OP exposure → Depression	-0.015	-0.170	0.020	-0.758	0.500
OP exposure → Impulsivity	-0.028	-0.323	-0.009	-3.107	0.010
Depression → Impulsivity	1.526	1.526	-0.567	2.691	0.010
Impulsivity → Depression	-2.098	-2.098	-1.148	-1.826	0.100
Depression → Suicide	0.407	0.407	0.193	2.110	0.050
Impulsivity → Suicide	0.372	0.372	0.062	5.972	<0.001

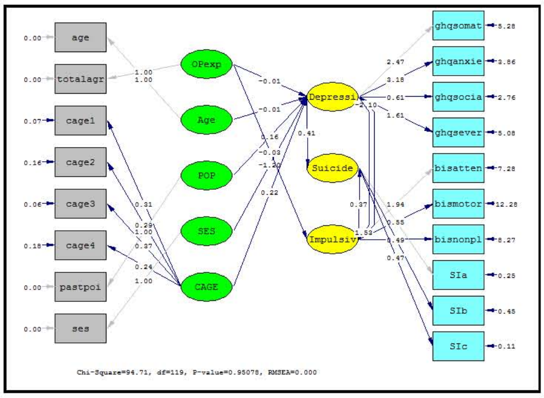

Figure 7.7 Model G

Table 7.8 Model estimates of model H

Path	Path coefficient unstandardised	Path coefficient standardised	standard error	*t*-score	*p*-value
Measurement model estimates					
Cage 1 → CAGE	0.308	0.751	-0.027	11.273	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.510	<0.001
Cage 3 → CAGE	0.373	0.842	-0.018	21.007	<0.001
Cage 4 → CAGE	0.242	0.492	-0.021	11.576	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.467	0.731	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.176	0.850	-0.209	15.208	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.608	0.343	-0.178	3.406	<0.001
GHQ subscale D (Severe depression) → Depression	1.612	0.581	-0.273	5.900	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.936	0.583	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.401	0.565	-0.282	8.522	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.250	0.828	-0.467	9.106	<0.001
SI subscale A (Desire for death) → Suicide	0.554	0.743	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.489	0.589	-0.140	3.490	<0.001
SI subscale C (Active suicide desire) → Suicide	0.472	0.814	-0.046	10.259	<0.001
Structural model estimates					
Age → Impulsivity	-0.005	-0.062	0.009	-0.639	>0.500
Socioeconomic status → Impulsivity	-0.573	-0.280	0.178	-3.226	0.010
CAGE → Impulsivity	0.104	0.104	0.073	1.423	0.200
Past history of OP poisoning → Impulsivity	0.077	0.028	0.177	0.434	>0.500
OP exposure → Impulsivity	-0.007	-0.081	0.008	-0.926	0.400
OP exposure → Depression	0.019	0.212	-0.006	2.972	0.010
Depression → Impulsivity	-0.477	-0.477	-0.261	-1.826	0.100
Impulsivity → Depression	0.655	0.655	-0.244	2.691	0.010
Depression → Suicide	0.407	0.407	0.193	2.110	0.050
Impulsivity → Suicide	0.372	0.372	0.062	5.972	<0.001

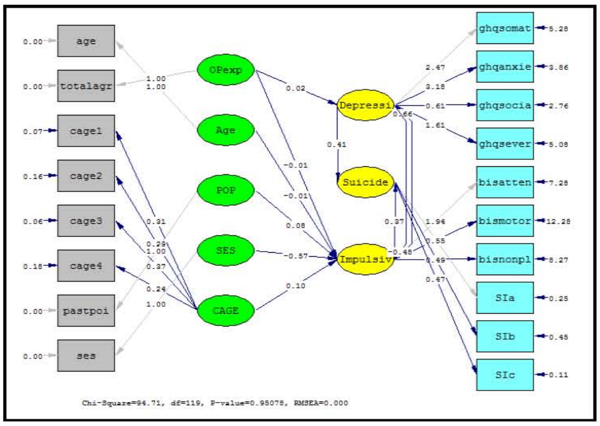

Figure 7.8 Model H

Table 7.9 Model estimates of model I

Path	Path coefficient unstandardised	Path coefficient standardised	standard error	*t*-score	*p*-value
Measurement model estimates					
Cage 1 → CAGE	0.308	0.751	-0.027	11.273	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.510	<0.001
Cage 3 → CAGE	0.373	0.842	-0.018	21.007	<0.001
Cage 4 → CAGE	0.242	0.492	-0.021	11.576	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.491	0.739	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.172	0.849	-0.209	15.140	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.604	0.341	-0.177	3.417	<0.001
GHQ subscale D (Severe depression) → Depression	1.596	0.575	-0.270	5.912	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.944	0.585	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.424	0.570	-0.278	8.723	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.207	0.820	-0.451	9.332	<0.001
SI subscale A (Desire for death) → Suicide	0.554	0.744	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.489	0.589	-0.140	3.485	<0.001
SI subscale C (Active suicide desire) → Suicide	0.472	0.813	-0.046	10.212	<0.001
Structural model estimates					
Age → Depression	0.001	0.015	0.189	2.326	0.050
Age → Impulsivity	-0.006	-0.067	0.007	-0.872	0.400
Socioeconomic status → Depression	-0.132	-0.065	0.074	0.970	0.400
Socioeconomic status → Impulsivity	-0.465	-0.277	0.216	-2.158	0.050
CAGE → Depression	0.072	0.072	0.095	0.700	0.500
CAGE → Impulsivity	0.058	0.058	0.094	0.616	>0.500
Past history of OP poisoning → Depression	0.439	0.016	0.410	-0.322	>0.500
Past history of OP poisoning → Impulsivity	-0.179	-0.065	0.348	-0.515	>0.500
OP exposure → Depression	0.008	0.096	0.012	0.111	>0.500
OP exposure → Impulsivity	-0.010	-0.119	0.008	-1.264	0.300
Depression → Impulsivity	0.056	0.056	-0.788	0.071	>0.500
Impulsivity → Depression	0.173	0.173	-0.796	0.217	>0.500
Depression → Suicide	0.400	0.400	0.191	2.096	0.050
Impulsivity → Suicide	0.378	0.378	0.063	5.991	<0.001

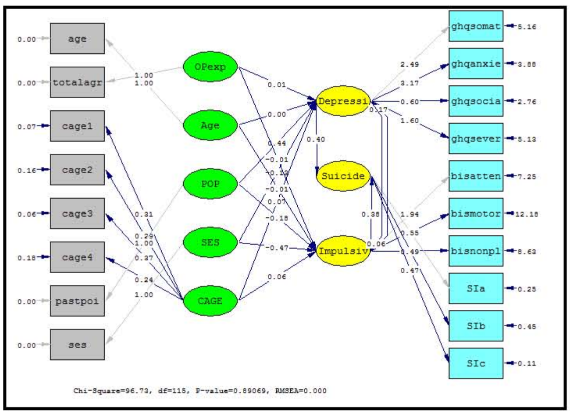

Figure 7.9 Model I

Table 7.10 Model estimates of model J

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.384	0.520	-0.700	6.259	<0.001
Hand spraying pesticides → OP exposure	5.626	0.622	-0.838	6.713	<0.001
Spraying pesticides using a backpack → OP exposure	3.921	0.488	-0.747	5.245	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.272	<0.001
Harvesting → OP exposure	9.219	0.963	-0.529	17.443	<0.001
Gardening → OP exposure	4.848	0.565	-0.834	5.816	<0.001
Dipping livestock → OP exposure	1.899	0.331	-0.599	3.170	0.010
Orchards → OP exposure	7.404	0.795	-0.656	11.281	<0.001
Cage 1 → CAGE	0.308	0.751	-0.027	11.291	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.386	<0.001
Cage 3 → CAGE	0.375	0.843	-0.018	20.909	<0.001
Cage 4 → CAGE	0.241	0.491	-0.021	11.507	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.459	0.729	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.188	0.854	-0.210	15.148	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.600	0.339	-0.179	3.350	<0.001
GHQ subscale D (Severe depression) → Depression	0.613	0.582	-0.273	5.918	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.926	0.580	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.388	0.562	-0.281	8.500	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.273	0.833	-0.476	8.983	<0.001
SI subscale A (Desire for death) → Suicide	0.553	0.743	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.489	0.589	-0.140	3.488	<0.001
SI subscale C (Active suicide desire) → Suicide	0.471	0.813	-0.046	10.196	<0.001
Structural model estimates					
Age → Depression	-0.022	-0.253	0.039	-0.568	>0.500
Socioeconomic status → Depression	-2.279	-1.113	1.970	-1.157	0.300
CAGE → Depression	0.388	0.388	0.495	0.784	0.500
Past history of OP poisoning → Depression	-0.080	-0.029	0.698	-0.115	>0.500
OP exposure → Depression	-0.593	-0.593	0.512	-1.156	0.300
OP exposure → Impulsivity	-0.056	-0.056	-0.112	-0.498	>0.500
Depression → Impulsivity	2.385	2.385	-1.241	1.922	0.100
Impulsivity → Depression	-4.458	-4.462	-4.121	-1.082	0.300
Depression → Suicide	0.406	0.406	0.193	2.106	0.050
Impulsivity → Suicide	0.372	0.372	0.062	6.007	<0.001

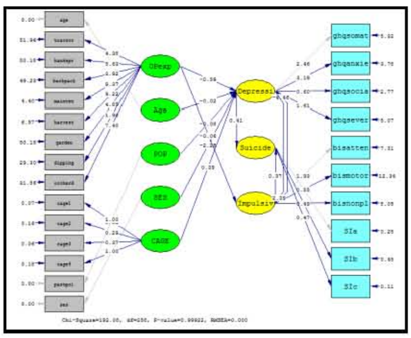

Figure 7.10 Model J

Table 7.11 Model estimates of model K

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.384	0.520	-0.700	6.259	<0.001
Hand spraying pesticides → OP exposure	5.626	0.622	-0.838	6.713	<0.001
Spraying pesticides using a backpack → OP exposure	3.921	0.488	-0.747	5.245	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.272	<0.001
Harvesting → OP exposure	9.219	0.963	-0.529	17.443	<0.001
Gardening → OP exposure	4.848	0.565	-0.834	5.816	<0.001
Dipping livestock → OP exposure	1.899	0.331	-0.599	3.170	0.010
Orchards → OP exposure	7.404	0.795	-0.656	11.281	<0.001
Cage 1 → CAGE	0.308	0.751	-0.027	11.291	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.386	<0.001
Cage 3 → CAGE	0.375	0.843	-0.018	20.909	<0.001
Cage 4 → CAGE	0.241	0.491	-0.021	11.507	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.462	0.730	_	_	_
GHQ subscale B (Anxiety and insomnia) → Depression	3.197	0.856	-0.207	15.448	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.597	0.337	-0.179	3.344	<0.001
GHQ subscale D (Severe depression) → Depression	1.605	0.579	-0.269	5.961	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.938	0.583	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.405	0.566	-0.277	8.673	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.239	0.826	-0.460	9.210	<0.001
SI subscale A (Desire for death) → Suicide	0.554	0.744	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.489	0.589	-0.140	3.493	<0.001
SI subscale C (Active suicide desire) → Suicide	0.471	0.813	-0.046	10.135	<0.001
Structural model estimates					
Age → Impulsivity	-0.009	-0.105	0.006	-1.424	0.200
Socioeconomic status → Impulsivity	-0.472	-0.230	0.127	-3.704	<0.001
CAGE → Impulsivity	0.057	0.057	0.064	0.891	0.400
Past history of OP poisoning → Impulsivity	-0.158	-0.058	0.137	-1.158	0.300
OP exposure → Impulsivity	-0.085	-0.085	0.058	-1.477	0.200
OP exposure → Depression	-0.029	-0.029	-0.049	-0.594	>0.500
Depression → Impulsivity	0.081	0.081	-0.076	0.461	>0.500
Impulsivity → Depression	0.128	0.128	-0.211	0.605	>0.500
Depression → Suicide	0.402	0.402	0.190	2.111	0.050
Impulsivity → Suicide	0.376	0.376	0.062	6.028	<0.001

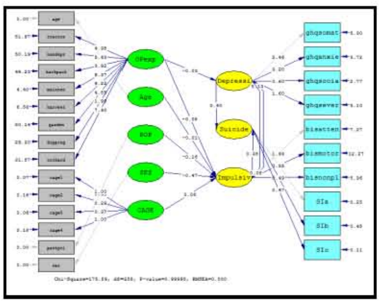

Figure 7.11 Model K

Table 7.12 Model estimates of model L

Path	Path coefficient unstandardised	Path coefficient standardised	standard error	*t*-score	*p*-value
Measurement model estimates					
Spraying from the back of a tractor → OP exposure	4.384	0.520	-0.700	6.259	<0.001
Hand spraying pesticides → OP exposure	5.626	0.622	-0.838	6.713	<0.001
Spraying pesticides using a backpack → OP exposure	3.921	0.488	-0.747	5.245	<0.001
Maintenance work → OP exposure	9.366	0.976	-0.486	19.272	<0.001
Harvesting → OP exposure	9.219	0.963	-0.529	17.443	<0.001
Gardening → OP exposure	4.848	0.565	-0.834	5.816	<0.001
Dipping livestock → OP exposure	1.899	0.331	-0.599	3.170	<0.001
Orchards → OP exposure	7.404	0.795	-0.656	11.281	<0.001
Cage 1 → CAGE	0.308	0.751	-0.027	11.291	<0.001
Cage 2 → CAGE	0.288	0.587	-0.023	12.386	<0.001
Cage 3 → CAGE	0.375	0.843	-0.018	20.909	<0.001
Cage 4 → CAGE	0.241	0.491	-0.021	11.507	<0.001
GHQ subscale A (Somatic symptoms) → Depression	2.512	0.741	–	–	–
GHQ subscale B (Anxiety and insomnia) → Depression	3.199	0.852	-0.211	15.182	<0.001
GHQ subscale C (Social dysfunction) → Depression	0.600	0.338	-0.176	3.408	<0.001
GHQ subscale D (Severe depression) → Depression	1.589	0.571	-0.269	5.914	<0.001
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.953	0.584	–	–	–
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.429	0.568	-0.277	8.763	<0.001
BIS subscale C (Nonplanning impulsiveness) → Impulsivity	4.242	0.822	-0.454	9.339	<0.001
SI subscale A (Desire for death) → Suicide	0.568	0.744	–	–	–
SI subscale B (Preparation for suicide) → Suicide	0.501	0.589	-0.144	3.483	<0.001
SI subscale C (Active suicide desire) → Suicide	0.483	0.812	-0.048	10.133	<0.001
Structural model estimates					
Age → Depression	0.016	0.183	0.007	2.246	0.050
Age → Impulsivity	-0.007	-0.079	0.008	-0.870	0.400
Socioeconomic status → Depression	0.022	0.011	0.152	0.148	>0.500
Socioeconomic status → Impulsivity	-0.502	-0.247	0.130	-3.869	<0.001
CAGE → Depression	0.079	0.080	0.052	1.527	0.200
CAGE → Impulsivity	0.076	0.077	0.075	1.024	0.400
Past history of OP poisoning → Depression	0.487	0.178	0.149	3.269	<0.001
Past history of OP poisoning → Impulsivity	-0.079	-0.029	0.201	-0.394	>0.500
OP exposure → Depression	-0.117	-0.117	0.067	-1.740	0.100
OP exposure → Impulsivity	-0.115	-0.116	0.070	-1.647	0.100
Depression → Impulsivity	-0.164	-0.164	-0.238	0.688	0.500
Impulsivity → Depression	0.371	0.371	-0.266	1.394	0.200
Depression → Suicide	0.387	0.395	0.185	2.090	0.050
Impulsivity → Suicide	0.373	0.380	0.062	6.001	<0.001

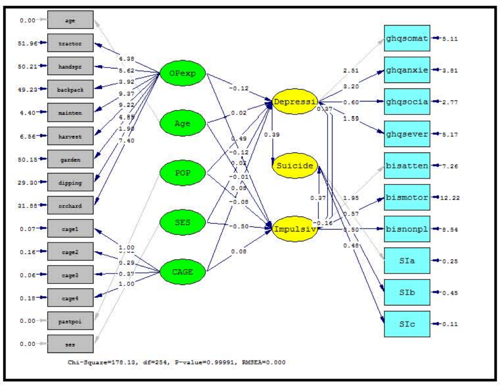

Figure 7.12 Model L

8. Appendix B

Table 8.1 Model estimates of model A2

Path	Path coefficient unstandardised	Path coefficient standardised	Standard error	*t*-score	*p*-value
Measurement model estimates					
Cage 1 → CAGE	0.308	0.750	0.028	11.189	<0.001
Cage 2 → CAGE	0.288	0.586	0.023	12.411	<0.001
Cage 3 → CAGE	0.373	0.843	0.018	21.014	<0.001
Cage 4 → CAGE	0.243	0.494	0.021	11.691	<0.001
GHQ subscale D (Severe depression) → Depression	2.164	0.781	–	–	–
SI subscale A (Desire for death) → Suicide	0.537	0.721	–	–	–
SI subscale B (Preparation for suicide) → Suicide	0.484	0.583	0.132	3.662	<0.001
SI subscale C (Active suicide desire) → Suicide	0.487	0.841	0.035	14.024	<0.001
Structural model estimates					
Age → Depression	-0.012	-0.140	0.008	-1.502	0.200
Socioeconomic status → Depression	-0.450	-0.220	0.162	-2.769	0.010
CAGE → Depression	0.023	0.024	0.059	0.401	>0.500
Past history of OP poisoning → Depression	0.005	0.002	0.131	0.040	>0.500
OP exposure → Depression	0.007	0.083	0.006	1.135	0.300
Depression → Suicide	0.478	0.730	-0.221	2.162	0.050

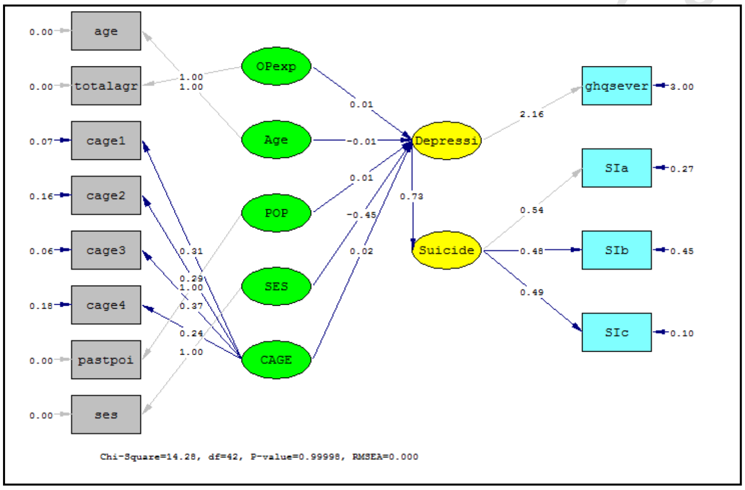

Figure 8.1 Model A2

Table 8.2 Model estimates of model I2

Path	Path coefficient		standard error	*t*-score	*p*-value
	unstandardised	standardised			
Measurement model estimates					
Cage 1 → CAGE	0.308	0.751	0.027	11.273	<0.001
Cage 2 → CAGE	0.289	0.587	0.023	12.510	<0.001
Cage 3 → CAGE	0.373	0.842	0.018	20.093	<0.001
Cage 4 → CAGE	0.242	0.492	0.021	11.576	<0.001
GHQ subscale D (Severe depression) → Depression	1.921	0.693	_	_	_
BIS subscale A (Attention Impulsiveness) → Impulsivity	1.931	0.581	_	_	_
BIS subscale B (Motor Impulsiveness) → Impulsivity	2.427	0.571	0.278	8.723	<0.001
BIS subscale C (Non-planning impulsiveness) → Impulsivity	4.207	0.824	0.451	9.332	<0.001
SI subscale A (Desire for death) → Suicide	0.554	0.742	_	_	_
SI subscale B (Preparation for suicide) → Suicide	0.489	0.589	0.138	3.544	<0.001
SI subscale C (Active suicide desire) → Suicide	0.472	0.814	0.043	11.073	<0.001
Structural model estimates					
Age → Depression	-0.009	-0.098	-0.009	-0.945	0.400
Age → Impulsivity	-0.010	-0.111	0.008	1.222	0.300
Socioeconomic status → Depression	-0.095	-0.046	0.111	-0.855	0.400
Socioeconomic status → Impulsivity	-0.640	-0.313	0.145	-4.413	<0.001
CAGE → Depression	-0.056	-0.056	0.070	-0.788	0.500
CAGE → Impulsivity	0.074	0.074	0.078	0.946	0.400
Past history of OP poisoning → Depression	0.125	0.045	0.133	0.938	0.400
Past history of OP poisoning → Impulsivity	-0.137	-0.050	0.172	-0.797	0.500
OP exposure → Depression	0.017	0.194	0.009	1.812	0.100
OP exposure → Impulsivity	-0.008	-0.089	0.007	-1.069	0.300
Depression → Impulsivity	-0.395	-0.395	0.128	-3.082	0.010
Impulsivity → Depression	0.766	0.766	0.237	3.236	0.010
Depression → Suicide	0.808	0.808	0.397	2.037	0.050
Impulsivity → Suicide	0.410	0.041	0.232	0.178	>0.500

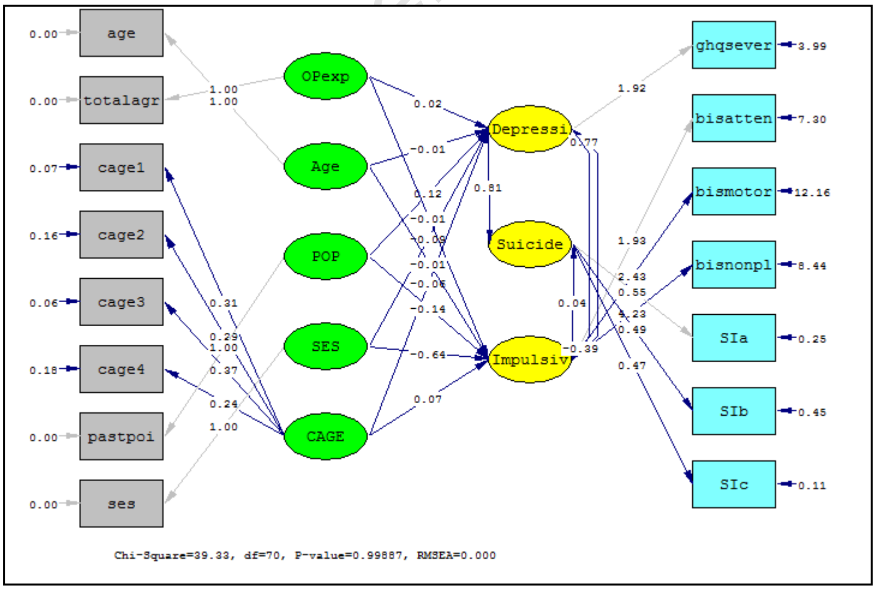

Figure 8.2 Model I2