



**Baker IDI Research Online**

<http://library.bakeridi.edu.au>

This is the postprint version of the work. It is the manuscript that was accepted by the journal following peer review. It does not include the publisher's layout and pagination.

**Burns RA, Byles J, Magliano DJ, Mitchell P, Anstey KJ. The utility of estimating population-level trajectories of terminal wellbeing decline within a growth mixture modelling framework. *Soc Psychiatry Psychiatr Epidemiol* 2015; 50(3): 479-87.**

<http://hdl.handle.net/11187/2199>

SHORT TITLE: Trajectories of Terminal Decline

The utility of estimating population-level trajectories of terminal wellbeing decline within a mixture modelling framework

Burns, R.A.,<sup>1\*</sup> Byles, J.,<sup>2</sup> Magliano, D. J.,<sup>3</sup> Mitchell, P.<sup>4</sup> & Anstey, K.J.<sup>1</sup>

<sup>1</sup>Centre for Research on Ageing, Health and Wellbeing, The Australian National University Canberra, ACT, AUSTRALIA; <sup>2</sup>Research Centre for Gender, Health and Ageing, University of Newcastle, Newcastle, NSW, AUSTRALIA; <sup>3</sup>Baker IDI Heart and Diabetes Institute, Melbourne, VIC, AUSTRALIA; <sup>4</sup>Centre for Vision Research, Westmead Millennium Institute and Department of Ophthalmology, the University of Sydney, Sydney, NSW, AUSTRALIA

\* Corresponding Author

Centre for Research on Ageing, Health and Wellbeing  
Building 62A,  
Eggleston Road  
The Australian National University  
Canberra 0200 ACT  
AUSTRALIA

[Richard.Burns@anu.edu.au](mailto:Richard.Burns@anu.edu.au)

Ph: +61 02 6125 3132

## **ABSTRACT**

**Purpose:** Mortality-related decline has been identified across multiple domains of human functioning, including mental health and wellbeing. The current study utilised a mixture modelling framework to establish whether terminal decline trajectories in wellbeing and mental health are consistently experienced in the years preceding death.

**Methods:** Participants were older-aged ( $M = 69.59$  years;  $SD = 8.08$  years) deceased females ( $N = 1,862$ ) from the Dynamic Analyses to Optimise Ageing (DYNOPTA) project. Growth mixture models analysed participants' responses on measures of mental health and wellbeing for up to 16 years from death.

**Results:** Multi-level models confirmed overall terminal decline and terminal drop in both mental health and wellbeing. However, modelling the same participants with a latent mixture growth model indicated that most participants reported stability in mental health (90.3%) and wellbeing (89.0%) in the years preceding death.

**Conclusions:** We confirmed other population-level analyses which support terminal decline and drop hypotheses in both mental health and wellbeing. However, we have subsequently identified that contrary to most population-level analyses, most of this effect is driven by a small, but significant minority of the population. Instead, most individuals report stable levels of mental health and wellbeing in the years preceding death.

**Keywords:** Well-being; Mental Health; Mortality; Epidemiology; Mixture modelling.

## **Introduction**

Mortality-related decline has been identified across several indices of human functioning including cognitive function [1-5], mental health and wellbeing [6-10]. The notion of terminal decline has been used to describe a pattern of change, specifically decline and decrement, in the years approaching mortality, while terminal drop relates to two specific phases of mortality-related change; a pre-terminal phase of stability or age-associated decline that is followed by a phase of accelerated decline in functioning as the individual approaches death [2].

Evidence for terminal decline and drop in wellbeing and mental health appears substantial. However, recently, a number of limitations of existing terminal decline research have been identified [10]. First, much of the existing literature fails to account for declines in other mortality-related health indicators. When adjusting for intra-individual changes in physical health, Burns et al [10] demonstrated that both terminal decline and drop in mental health and wellbeing were attenuated. Second is the assumption that mortality-related decline is consistent between different indicators of wellbeing [8]. More recent evidence suggests that mortality-related decline is present in some wellbeing indices and not others, or more pronounced in one index over another [9, 10]. Perhaps most significantly, a limitation of existing terminal decline research is the assumption that a single population pattern of decline accurately describes the lived experience of older adults. Whilst multi-level or latent growth models incorporate random effects which allow for between-person variation over time, they still estimate an overall population-level trajectory around which all individual trajectories follow. These methods assume population homogeneity in the change around a common growth trajectory and it may be that this is not the most appropriate method by which to accurately estimate terminal decline changes. Rather we hypothesize that individuals may respond in quite different ways with approaching mortality. Simply, typical analytical

approaches ‘assume’ an overall population-level decline trajectory describes the mortality-related experience for most. Whilst some may indeed decline, others may actually be stable or even improve in mental health in the years leading to death. This inter-individual variation is particularly pertinent since different causes of death may significantly impact on the utility of observing terminal decline. As Burns et al [10] highlighted, most population-level surveys of the terminal decline hypothesis ignore this very important point; they examine the associations with all-cause mortality. It would be appropriate to assume that those who experience unexpected death (e.g. accidental death) may report quite different trajectories from those whose mortality may be due to illness. Indeed we could hypothesize that they might even demonstrate no decline. Further, we might even expect quite different trajectories for those who experience either chronic or acute illness. This leads us to question the extent to which terminal decline/drop truly reflects normative experience for older adults in the years approaching death. Consequently, the current paper seeks to extend prior terminal decline/drop findings by examining the extent to which terminal decline is a common experience amongst older adults across indices of wellbeing and mental health.

Mortality-related decline across multiple indicators of wellbeing and mental health are not consistent [9, 10]. This is not surprising since a growing wellbeing literature discriminates between distinct components of mental health and wellbeing [11] and there is support for distinguishing between correlated dimensions of wellbeing [12, 13]. For the current paper we define mental health and wellbeing in terms of psychological distress and vitality. Vitality reflects psychological energy and engagement [14] and is positively related to self-esteem, intrinsic motivation and mindfulness [14, 15], and negatively related to depression and anxiety and a range of physical health conditions including cardiovascular disorders, diabetes, hypertension, prostate disease, falls and mortality risk [16-20]. In the current paper, we 1) utilize a latent growth mixture modelling framework to identify classes

of population heterogeneity in growth trajectories by allowing for trajectories of mental health and wellbeing for sub-populations of decedents and 2) examine the socio-demographic and health characteristics of individuals within different classes that reflect different mortality-related trajectories of wellbeing.

## **Method**

### ***Participants***

Data were drawn from the DYNOPTA project [21]. DYNOPTA involves harmonizing data from nine Australian longitudinal studies of ageing. Ethical approval was obtained for all individual studies from relevant supervisory bodies (see acknowledgement), while ethical approval for the DYNOPTA project was approved by the Australian National University Human Research Ethics Committee in accordance with National guidelines and the ethical standards laid down in the 1964 Declaration of Helsinki. The harmonization of existing studies, by pooling data or parallel analysis, is increasingly recognized as an important method that contributes to and addresses the limitations of investment in individual longitudinal studies [22]. Overall, there were 50,652 respondents in the pooled DYNOPTA dataset at baseline, which was conducted between 1990 and 2001. Of the five contributing studies to DYNOPTA providing the necessary wellbeing variables, only four provided data on mortality, two of which were the Australian Longitudinal Study of Women's Health (ALSWH) 1946-51 and 1921-26 birth cohorts. Consequently, a significant proportion of participants were female (93%), therefore we restrict our analyses to females only, and for whom mortality data was available. Therefore, the final sample for this study comprises decedent female participants ( $N = 1,862$ ) who were aged 69.59 years ( $SD = 8.08$  years) at baseline and were observed on at least two occasions up to a maximum of 4 occasions over a 13 year ( $M = 3.09$ ;  $SD = 1.02$ ) period from baseline observation. The timing of measurement

occasions occurred on average 3.11 years ( $SD = 1.5$ ), 5.78 years ( $SD = .43$ ) and 8.73 years ( $SD = .46$ ) from baseline. All participants were eventual decedents who were observed from up to 16 years ( $M = 6.04$ ;  $SD = 2.14$ ) from death. Of 1,862 decedents who completed a minimum of two observations, 1754 (94 % of sample) completed three observations, and 1,084 (58 % of sample) four observations.

### **Measures**

*Wellbeing: Vitality and Mental Health.* Wellbeing variables were derived from the Short-Form Health Survey-36 (SF-36) [23]. The vitality and mental health indexes partly contribute to the SF-36 Mental Health Component Score. The vitality subscale comprises four items including, 'Feel full of life', 'Have a lot of energy', 'Felt worn out', 'Felt tired'. The mental health subscale has been validated against clinical measures of depression [24] and has been used in epidemiological studies worldwide as an indicator psychological distress [25, 26]. The mental health subscale comprises five items including, 'Been a nervous person', 'Felt so down in the dumps nothing could cheer you up', 'Felt calm and peaceful', 'Felt down', 'Been a happy person'. For both the vitality and mental health subscales, participants indicated the extent to which they experienced each statement on a 6-point Likert-type scale, ranging from '0' (*None of the Time*) to '6' (*All of the Time*) over the preceding four weeks. Despite moderate cross-sectional correlations between vitality and mental health in the DYNOPTA study over time with reported magnitudes of between  $r = 0.46$  and  $r = 0.58$ , a significant amount of variance remains unexplained in either construct such as to warrant treating these variables as independent indicators of positive and negative dimensions of wellbeing. Discriminating between related but distinct vitality and mental health constructs has been previously established in the DYNOPTA sample [20, 27].

*Time Dimension.* In our analyses, we utilized a distance-to-death time metric that reflects the difference in time of each observation from the time of death for each participant; we

annualized this metric so that each time measurement pre-mortality reflected an annual change. Participants were assessed at intervals of at least 1-year.

*Covariates: Socio-demographic and health variables.*

Time invariant covariates included *Baseline Age*, which was centered at 45 years (the lowest age in DYNOPTA), *Education Status* which were defined as ‘No Post-School Education’ (the reference category; coded as 0); and any ‘Post-School Education’ (coded as 1), *Partner Status*, which was simply defined as ‘Partnered’ (the reference category; coded as 0) and ‘Not Partnered’ (coded as 1), and *Physical Health* which was assessed with the SF-36 Physical Component Score [23] which incorporates measures of physical functioning, general health, role-physical and bodily pain that have been validated against objective health indicators [28], including cardiac disease [29], diabetes mellitus [30], stroke [31], low back pain [32], lung disease [33], and renal disease [34].

### ***Statistical Analysis***

Vitality and mental health were *T*-scored ( $M = 50$ ;  $SD = 10$ ), standardized to baseline observation and coded so that high scores reflected positive health status. All statistical analyses were undertaken in MPlus v.7.1. Following previously published findings of mortality-related population studies into mortality related decline [7], incomplete data are treated as missing at random [35]. We implemented latent Growth Mixture Modeling (GMM) [36] to estimate classes of trajectories for vitality and mental health separately from a Latent Growth Model (LGM) that incorporated linear and quadratic trajectories. The intercepts for both vitality and mental health were centered at the last year before death.

First, we estimated an LGM that can be parameterized as:

(1)

where the wellbeing score,  $WB_{it}$  is independently estimated for vitality and mental health, for person  $i$  at time  $t$ , and is a function of  $\beta 0_i$ , an individual-specific intercept parameter,  $\beta 1_i$  and  $\beta 2_i$ , individual-specific linear and quadratic slope parameters that respectively capture terminal decline and drop over time, and  $e_{it}$ , the residual error. The slope parameters  $\beta 1_{it}$  and  $\beta 2_{it}$  are assumed to be normally distributed around a group mean, correlated with the  $\beta 0_{it}$  and uncorrelated with the residual errors,  $e_{it}$ .

However, the LGM assumes that individuals are drawn from a single population with common parameters. This assumption can be relaxed by applying a GMM to the LGM which allows for differences in intercept and growth parameters for unobserved subpopulations. A number of goodness of fit indices (GFI) were then used determine the most appropriate number of classes to be drawn. The Akaike information criterion (AIC) and adjusted Bayesian information criterion (BIC), were used to assess model fit on the basis that a smaller fit indicated a model with better fit of the data to the model. The Lo, Mendell, and Rubin [37] likelihood ratio test (LMR-LRT), the adjusted likelihood ratio test (LRT), and the bootstrap likelihood ratio test (BLRT) statistics were used to compare  $k$  classes with  $k-1$  classes (see Nylund, Asparouhov & Muthen [38], for a more substantive discussion on fit indices for identifying mixture classes). However, we were also guided by other factors in determining the number of classes to extract. These factors included, issues of parsimony, theoretical justification, and interpretability [39, 40]. For instance, we would find little utility in extracting a further class if its proportion was very low and if its properties were similar to another class. We then saved class probabilities from this unconditional model to compare socio-demographic and physical health characteristics between individuals in the different mental health and wellbeing classes.

## Results

### *Population level terminal decline in mental health and vitality*

We first estimated the extent of terminal decline in both vitality and mental health in unadjusted LGMs. For vitality, significant linear ( $\beta = -1.43$ ;  $SE = 0.17$ ;  $p < .001$ ) and quadratic ( $\beta = -0.08$ ;  $SE = 0.02$ ;  $p < .001$ ) slopes were reported with the model reporting excellent fit to the data ( $\chi^2 = 56.153$ ;  $df = 40$ ;  $p = .046$ ;  $RMSEA = .015$  (95% CI: .002 - .024);  $CFI = 0.986$ ). For mental health, significant linear ( $\beta = -0.63$ ;  $SE = 0.17$ ;  $p < .001$ ) and quadratic ( $\beta = -0.05$ ;  $SE = 0.02$ ;  $p = .007$ ) slopes were reported with the model reporting excellent fit to the data ( $\chi^2 = 52.827$ ;  $df = 40$ ;  $p = .084$ ;  $RMSEA = .013$  (95% CI: .000 - .022);  $CFI = 0.989$ ). This result provides evidence for an overall population decline in both wellbeing and mental health and confirms other population-level evidence for terminal decline and drop.

### *Identifying subpopulations of terminal decline in mental health and vitality*

We extended our unadjusted LGMs and estimated multiple trajectory classes for both vitality and mental health within a mixture modelling framework. Initial GMMs identified negative variances for the linear and quadratic slope factors for both vitality and mental health, so we therefore constrained our slope factors to zero. By constraining the variance of slope factors to zero, the GMM now reflects a Latent Class Growth Analysis (LCGA) which is a special form of GMM in which the variances and covariances are constrained to zero and allow for faster convergence of the model parameters [41]. Comparison of the intercept and slope factor estimates did not differ substantively when constraining these slope factor variances to zero. Also, model fit indices between the constrained and unconstrained models were comparable. Therefore, we constrained our slope factors to zero in all subsequent analyses as a form of LCGA. This suggests that individuals within different classes are homogenous in the way they change over time.

Model fit indices for mixture models for mental health and vitality are summarized in Table 1. For Mental Health, lower AIC and adjusted BIC values were reported for up to 6 classes, whilst bootstrap LRT indicated that 6 classes were a better fit to the data than a 5-class model. However, these findings need to be balanced by the very low proportions reported in the 6 class model whereby 3 of the classes reported proportions of less than 5%. Consequently, for mental health, we report the findings of the 5-class model where only 2 classes now reported proportions below 5%. As these classes were identified in the 3 and 4-class mixture analyses, we retained them as valid unique groups since they were consistently reported in earlier mixture analyses and as they differed substantially from the trajectories of the other classes. For vitality, lower AIC and adjusted BIC values and a significant bootstrap LRT were reported for up to 6 classes. However, no significant differences on the LRT or adjusted LRT were indicated from models estimating 3 or more classes. Similar to the findings for mental health, very low proportions were reported for 3 classes in the 6 class model; 1 class reported proportions of less than 10% - 1 class with less than 5% and another with less than 1% . Consequently, we report the findings of the 5-class model where only 1 class now reported proportions below 5% (4.5%) and was identified in earlier mixture analyses suggesting that this group was identified as substantially different from other classes.

**INSERT TABLE 1**

**INSERT FIGURE 1**

**INSERT FIGURE 2**

Visual representations of the different trajectories reported for these different vitality and mental health classes are presented in figures 1 and 2. A visual inspection reveals three stable groups for vitality (Figure 1), with two groups reflecting different types of decline; one class (class 5) reflects a minority (6.9%) of individuals who reported a gradual terminal decline in vitality in the years preceding death, whilst a second decline group (class 2) reflects a group of individuals (4.5) who are relatively stable and report a significant terminal drop only in the years immediately preceding death. The majority of individuals showed little change in the scores across all observations, with classes differences reflecting changes in intercept rather than decline in vitality scores. For mental health (Figure 2), 3 stable groups were also reported. In contrast to vitality, only one decline group was identified for mental health (class 4, 6%) which reflected a terminal drop, a period of stability followed by a sudden precipitous drop in the years leading to death. One class (Class 2, 3.7%) reported increasing mental health in the years preceding death, a finding that was not identified in the analysis of vitality. The other three classes showed little change in mental health over the time preceding death, with a majority of decedents (69.3%) showing stable and relatively high mental health scores across all observations.

**INSERT TABLE 2**

**INSERT TABLE 3**

Fixed estimates for the intercept and slope factors for each mental health and vitality mixture class are presented in Tables 2 and 3 respectively. Overall, and as expected, substantial linear declines were reported for those who reported terminal decline in vitality. Similarly, substantive linear and quadratic decline was reported for those in the Terminal Drop classes for both mental health (Class 4) and vitality (Class 5). As variables were T-Scored direct comparisons can be made and it is clear the terminal drop estimates are of comparable size.

The increase in mental health for those in the Improvers class (Class 2) was clear and substantive. For vitality, small but significant linear declines were reported for the Stable-Low (Class 3) and Stable-High (Class 4) classes. However, we would balance this significant findings by the large sample size, and given the size of these effects, we would argue that these effects indicate only small changes in comparison with the Terminal Decline and Terminal Drop classes which reported change several times that of these 'stable' groups.

#### *Discriminating socio-demographic characteristics of subpopulations of terminal decline*

Socio-demographic characteristics of each class are reported for mental health (Table 2) and vitality (Table 3). There were significant age differences between mental health classes ( $F = 5.51 (4, 1772) p < .001$ ). However, Bonferroni-adjusted comparisons between classes indicated that only those in the Stable-High class (Class 5) were significantly older at baseline than those who were Stable-Low (Class 1;  $p = .005$ ) and those in the Improvers class (Class 2;  $p = .033$ ). No other age differences were reported. Significant differences between classes were indicated for post-school education ( $\chi = 21.04 (4), p < .000$ ). Specifically, in comparison to those who were in the Stable-Low class (Class 1), post-school education was more likely reported by those who were in the Stable-High (Class 5;  $OR = 7.45 (5.38) p = .005$ ) or Stable-Average classes (Class 3;  $OR = 5.86 (4.31) p = .016$ ). No other differences for post-school education were reported suggesting education is not associated with terminal-drop. No differences in partner-status were reported between mental health classes ( $\chi = 4.53 (4), p = .340$ ). We then examined differences between mental health classes on vitality and physical health covariates. Significant differences in level of vitality were reported between mental health classes ( $F = 74.97 (4, 1772) p < .001$ ). Bonferroni-adjusted comparisons indicated that those in the Stable-High mental health class (Class 5) reported higher vitality in comparison with all other groups ( $p < .001$ ), whilst those in the Stable-Low class (Class 1)

reported lower vitality in comparison with all other groups ( $p < .00$ ). No other differences were reported. Differences vitality change were also reported between mental health classes ( $F = 72.82 (4, 1772) p < .001$ ). All classes were significantly different ( $p < .001$ ) except for those in the Stable-Average (Class 3) and Improver (Class 2) classes. Significant differences were reported between mental health classes on physical health intercept ( $F = 11.33 (4, 1772) p < .001$ ). Bonferroni comparisons indicated that those in the Stable-High class (Class5) reported significantly higher physical health in comparison with those in the Stable-Low (Class 1;  $p < .001$ ), Stable-Average (Class 3;  $p < .001$ ), and Terminal Decline (Class 4;  $p < .05$ ) classes. No other significant differences in level of mental health were reported between mental health classes. Significant differences were reported in physical health change between mental health classes ( $F = 6.38 (4, 1772) p < .001$ ). Those in the Stable-High class (Class5) reported significantly lower rates of change in physical health in comparison with the Stable-Low (Class 1;  $p < .01$ ) and Stable-Average (Class 3;  $p < .05$ ) classes. Those in the Terminal Decline class reported significantly lower rates of change in physical health in comparison with the Stable-Low (Class 1;  $p < .01$ ) and Stable-Average (Class 3;  $p < .05$ ) classes.

There were significant differences between vitality classes on baseline age ( $F = 3.42 (4, 1772) p = .009$ ). However, Bonferroni adjusted comparison of classes indicated that those in the Stable-Average class (Class 1) were older at baseline than those who were Stable-Low (Class 3;  $p = .039$ ) only. No other age differences were reported. No significant differences between vitality classes were reported for partner ( $\chi = 5.45 (4), p = .245$ ) or education ( $\chi = 9.26 (4), p = .055$ ) status. Significant differences were reported between vitality classes on Mental Health intercept ( $F = 101.67 (4, 1772) p < .001$ ). Bonferroni post-hoc comparisons indicated that those in the Stable-High class (Class 4) reported higher mental health than all other groups ( $p < .001$ ). Those in the Stable-Average (Class 1) and Terminal Drop classes

(Class 2) reported higher mental than those in the Stable-Low (Class 3) and Terminal-Drop (Class 4) classes (Class 5;  $p < .001$ ). Significant differences were reported between vitality classes in Mental Health changes ( $F = 12.72 (4, 1772) p < .001$ ). Specifically, those in all stable classes reported significantly lower changes in vitality in comparison with those in the Terminal Drop (Class 2) and Terminal-Drop (Class 4) classes ( $p < .001$ ). Significant differences in physical health were reported between vitality classes ( $F = 189.79 (4, 1772) p < .001$ ). Bonferroni post-hoc comparisons indicated that those in the Stable-High class (Class 4) reported higher physical health than all other classes ( $p < .001$ ). Those in the Stable-Average class (Class 1) reported higher physical health than all other groups ( $p < .001$ ) except for the Stable-High class (Class 4). No other differences were reported. Significant differences in change in physical health were reported between all vitality classes ( $F = 81.82 (4, 1772) p < .001$ ).

## **Discussion**

Overall, despite a substantial body of work that has identified mortality-related decline in mental health and wellbeing [6-10], we provide evidence that terminal decline and drop are not typical patterns of behaviour within a general population in later life. Instead, our findings suggest that for most, mental health and wellbeing are relatively stable in the years preceding death. Whilst small proportions of the population reported terminal drop in both mental health and wellbeing and terminal decline in wellbeing, a surprising result was that a small proportion of the sample (3.7%) actually reported increases in mental health in the years approaching death.

Whilst socio-demographic differences were identified between mental health and wellbeing classes, few of these covariates actually distinguished between stable and decline groups. For example, those in the Stable-High mental health class (Class 5) reported higher levels of vitality in comparison with those in the Stable-Low mental health class (Class 1), no

difference with either the terminal decline or improver classes were reported. The only example for substantive differences between stable and decline groups occurred for those in the Terminal Decline class (Class 4) who reported the largest declines in physical health and vitality of all mental health classes. Similarly, for vitality, differences between stable classes and decline classes were indicated for change in mental health and physical health only. Those in the decline (Class 5) and drop (Class 2) classes reported the largest declines in other health covariates, in comparison with the stable groups. Previously, Burns *et al* [10] indicated limitations of much population-level analyses of terminal decline which typically ignore cause of death. Similarly, we cannot discount that different causes of mortality and illness progression may impact on particular wellbeing and mental health trajectories in the different classes. Unfortunately, DYNOPTA data precludes our investigating cause of death further. Our investigation did include a measure of education as a proxy for socio-economic status, but other areas warrant further investigation, including occupation and income. With more sensitive indicators stronger correlates of and trajectories in older age and in the period leading to death may be identified.

A number of methodological issues warrant addressing. In our analysis, we initially implement GMMs to identify sub-population trajectories for mental health and wellbeing. However, despite convergence, our initial analyses identified negative variances for the linear and quadratic slope factors for both our health variables in various classes, and we therefore constrained our slope factors to zero. By constraining our slope factors to zero, we actually implemented a Latent Class Growth Analysis (LCGA) as a special form of GMM. The reasons are not difficult to identify; whilst our participants provided between 2-4 observations over several years prior to death, we were left with considerable sparse and unbalanced distribution of the observations. The use of LCGA, whereby the variances and covariances are constrained to zero, has previously been reported as a suitable alternative and allows for

faster convergence of the model parameters [41]. As we reported, comparison of our intercept and slope factor estimates did not differ substantively when constraining these slope factor variances to zero, so we therefore are confident in the efficiency of our model estimates. Furthermore, by restricting our random slope variances to zero, we can be more confident that each sub-population class comprises a homogenous group of individuals who change in the same way. Alternatively, utilizing a Bayesian estimation, whereby the prior distribution for variances are defined as positive, may be one other alternative to consider in order to allow the random slope variances to be freely estimated.

In conclusion, terminal decline and terminal drop are not typical for older adults as they approach their death. Whilst other findings have questioned the veracity of terminal decline to describe mental health and wellbeing changes, in particular recognising the role of intra-individual changes in other health conditions [10], the current study has implemented a general mixture approach to identify that classes of subpopulations do not report mental health or wellbeing decline in the years leading to death. Importantly, only a small proportion of the population reported terminal decline/drop in mental health and wellbeing, whilst a small proportion actually reported an increase in mental health.

## **Acknowledgements**

This work was supported by a National Health and Mental Medical Research Council grant (# 410215). The data on which this research is based were drawn from several Australian longitudinal studies including: the Australian Longitudinal Study of Ageing (ALSA), the Australian Longitudinal Study of Women's Health (ALSWH), the Australian Diabetes, Obesity and Lifestyle Study (AusDiab), the Blue Mountain Eye Study (BMES), the Canberra Longitudinal Study of Ageing (CLS), the Household, Income and Labour Dynamics in Australia study (HILDA), the Melbourne Longitudinal Studies on Healthy Ageing (MELSHA), the Personality And Total Health Through Life Study (PATH) and the Sydney Older Persons Study (SOPS). These studies were pooled and harmonized for the Dynamic Analyses to Optimize Ageing (DYNOPTA) project. All studies would like to thank the participants for volunteering their time to be involved in the respective studies. Details of all studies contributing data to DYNOPTA, including individual study leaders and funding sources, are available on the DYNOPTA website (<http://DYNOPTA.anu.edu.au>). The findings and views reported in this paper are those of the author(s) and not those of the original studies or their respective funding agencies. Burns is supported by the Australian Research Council Centre of Excellence in Population Ageing Research (project #: CE110001029). Anstey is funded by an NHMRC Fellowship #1002560.

**Conflict of interest:**

On behalf of all authors, the corresponding author states that there is no conflict of interest.

CONFIDENTIAL

## References

1. Batterham, P.J., et al., *Comparison of age and time-to-death in the dedifferentiation of late-life cognitive abilities*. Psychol Aging, 2011. **26**(4): p. 844-51.
2. Bäckman, L., et al., *Death and cognition: Synthesis and outlook*. Eur Psychol, 2006. **11**(3): p. 224-235.
3. Bosworth, H.B., et al., *Terminal change in cognitive function: an updated review of longitudinal studies*. Exp. Aging Res., 2002. **28**(3): p. 299-315.
4. Sliwinski, M.J., et al., *Modeling memory decline in older adults: the importance of preclinical dementia, attrition, and chronological age*. Psychol Aging, 2003. **18**(4): p. 658-71.
5. Sliwinski, M.J., et al., *On the importance of distinguishing pre-terminal and terminal cognitive decline*. Eur Psychol, 2006. **11**: p. 172-181.
6. Gerstorf, D., et al., *Life satisfaction shows terminal decline in old age: longitudinal evidence from the German Socio-Economic Panel Study (SOEP)*. Dev. Psychol., 2008. **44**(4): p. 1148-59.
7. Gerstorf, D., et al., *Decline in life satisfaction in old age: longitudinal evidence for links to distance-to-death*. Psychol Aging, 2008. **23**(1): p. 154-68.
8. Gerstorf, D., et al., *Late-life decline in well-being across adulthood in Germany, the United Kingdom, and the United States: Something is seriously wrong at the end of life*. Psychol Aging, 2010. **25**(2): p. 477-85.
9. Vogel, N., et al., *Time-to-death-related change in positive and negative affect among older adults approaching the end of life*. Psychol Aging, 2013. **28**(1): p. pp.
10. Burns, R.A., et al., *Trajectories of terminal decline in the wellbeing of older women: The DYNOPTA project*. Psychol Aging, in press.
11. Huppert, F.A., et al., *Measuring Well-being Across Europe: Description of the ESS Well-being Module and Preliminary Findings*. Soc Indic Res, 2009. **91**(3): p. 301-315.
12. Burns, R.A., et al., *Investigating the Structural Validity of Ryff's Psychological Well-Being Scales Across Two Samples*. Soc Indic Res, 2009. **93**(2): p. 359-375.
13. Gallagher, M.W., et al., *The Hierarchical Structure of Well-Being*. J Pers Soc Psychol, 2009. **77**(4): p. 1025-1050.
14. Ryan, R.M., et al., *On energy, personality, and health: subjective vitality as a dynamic reflection of well-being*. J Pers Soc Psychol, 1997. **65**(3): p. 529-65.
15. Kasser, T., et al., *Further examining the American dream: Differential correlates of intrinsic and extrinsic goals*. Pers Soc Psychol B, 1996. **22**(3): p. 280-287.
16. Nix, G.A., et al., *Revitalization through self-regulation: The effects of autonomous and controlled motivation on happiness and vitality*. J Exp Soc Psychol, 1999. **35**(3): p. 266-284.
17. Bjorner, J.B., et al., *Interpreting score differences in the SF-36 Vitality scale: using clinical conditions and functional outcomes to define the minimally important difference*. Curr Med Res Opin, 2007. **23**(4): p. 731-9.
18. Croog, S.H., et al., *The effects of antihypertensive therapy on the quality of life*. N Engl J Med, 1986. **314**(26): p. 1657-64.
19. Fowler, F.J., Jr., et al., *Symptom status and quality of life following prostatectomy*. J Amer Med Assoc, 1988. **259**(20): p. 3018-22.
20. Burns, R.A., et al., *Positive components of mental health provide significant protection against likelihood of falling in older women over a 13-year period*. International Psychogeriatrics, 2012. **24**(9): p. 1419-1428.
21. Anstey, K.J., et al., *Cohort profile: The Dynamic Analyses to Optimize Ageing (DYNOPTA) project*. Int J Epidemiol, 2010. **39**(1): p. 44-51.
22. Noale, M., et al., *Predictors of mortality: an international comparison of socio-demographic and health characteristics from six longitudinal studies on aging: The CLESA project*. Exp Gerontol, 2005. **40**: p. 89-99.

23. Ware, J.E., Jr., et al., *The factor structure of the SF-36 Health Survey in 10 countries: results from the IQOLA Project. International Quality of Life Assessment.* J Clin Epidemiol, 1998. **51**(11): p. 1159-65.
24. Rumpf, H.J., et al., *Screening for mental health: validity of the MHI-5 using DSM-IV Axis I psychiatric disorders as gold standard.* Psychiatry Res, 2001. **105**(3): p. 243-53.
25. Skapinakis, P., et al., *Mental health inequalities in Wales, UK: multi-level investigation of the effect of area deprivation.* Br J Psychiatry, 2005. **186**: p. 417-22.
26. Gill, S.C., et al., *Mental health and the timing of men's retirement.* Soc Psychiatry Psychiatr Epidemiol, 2006. **41**(7): p. 515-22.
27. Bartsch, L.J., et al., *Examining the SF-36 in an older population: analysis of data and presentation of Australian adult reference scores from the Dynamic Analyses to Optimise Ageing (DYNOPTA) project.* Qual Life Res, 2011. **20**(8): p. 1227-36.
28. Kravitz, R.L., et al., *Differences in the mix of patients among medical specialties and systems of care. Results from the medical outcomes study.* J Amer Med Assoc, 1992. **267**(12): p. 1617-23.
29. Zhang, J.P., et al., *Association of SF-36 with coronary artery disease risk factors and mortality: a PreCIS study.* Prev Cardiol, 2010. **13**(3): p. 122-9.
30. Davidson, M.B., *SF-36 and diabetes outcome measures.* Diabetes Care, 2005. **28**(6): p. 1536-7.
31. Kappelle, L.J., et al., *Prognosis of young adults with ischemic stroke. A long-term follow-up study assessing recurrent vascular events and functional outcome in the Iowa Registry of Stroke in Young Adults.* Stroke, 1994. **25**(7): p. 1360-5.
32. Garratt, A.M., et al., *The SF36 health survey questionnaire: an outcome measure suitable for routine use within the NHS? BMJ, 1993. 306(6890): p. 1440-4.*
33. Viramontes, J.L., et al., *Relationship between symptoms and health-related quality of life in chronic lung disease.* J Gen Intern Med, 1994. **9**(1): p. 46-8.
34. Osthus, T.B., et al., *Mortality and health-related quality of life in prevalent dialysis patients: Comparison between 12-items and 36-items short-form health survey.* Health Qual Life Outcomes, 2012. **10**: p. 46.
35. Little, R.J.A., et al., *On Jointly Estimating Parameters and Missing Data by Maximizing the Complete-Data Likelihood.* Am Stat, 1983. **37**(3): p. 218-220.
36. Muthen, B., et al., *Item response mixture modeling: application to tobacco dependence criteria.* Addict Behav, 2006. **31**(6): p. 1050-66.
37. Lo, Y.T., et al., *Testing the number of components in a normal mixture.* Biometrika, 2001. **88**(3): p. 767-778.
38. Nylund, K.L., et al., *Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study.* Structural Equation Modeling-a Multidisciplinary Journal, 2007. **14**(4): p. 535-569.
39. Bauer, D.J., et al., *Distributional assumptions of growth mixture models: implications for overextraction of latent trajectory classes.* Psychol Methods, 2003. **8**(3): p. 338-63.
40. Muthen, B., *Statistical and substantive checking in growth mixture modeling: comment on Bauer and Curran (2003).* Psychol Methods, 2003. **8**(3): p. 369-77; discussion 384-93.
41. Kreuter, E., et al., *Longitudinal modeling of population heterogeneity: Methodological challenges to the analysis of empirically derived criminal trajectory profiles.*, in *Advances in Latent Variable Mixture Models*, G.R. Hancock, et al., Editors. 2007, Information Age Publishing: Charlotter, NC

Table 1 *Model fit Indices for latent growth mixture models for mental health and vitality: the DYNOPTA study*

Class	Mental Health					Vitality				
	AIC	BIC	LMR-LRT	LRT	BLRT	AIC	BIC	LMR-LRT	LRT	BLRT
2	30172	30218	220.06	212.95	220.06*	30517	30563	63.70*	61.64*	63.70*
3	30093	30148	86.78*	83.97*	86.78*	30502	30552	16.41	25.38	16.41*
4	30026	30086	81.89	79.25	81.89*	30483	30543	26.23	25.39	26.23*
5	29968	30037	73.12	70.76	73.12*	30453	30522	38.48	37.24	38.48*
6	29924	30002	51.97	50.29	51.97*	30439	30517	39.64	38.36	39.64*

\*  $p < .001$  for k-1 classes AIC: Akaike information criterion; BIC: adjusted Bayesian information criterion; LMR-LRT: Lo, Mendell, and Rubin likelihood ratio test; LRT: the adjusted likelihood ratio test; BLRT: bootstrap likelihood ratio test

Table 2 *Socio-demographic characteristics and Fixed Effects for mental health trajectories by mixture class*

	Class 1:	Class 2:	Class 3:	Class 4:	Class 5:
	Stable - Low	Improvers	Stable - Average	Terminal Drop	Stable - High
	$\beta$ (SE)	$\beta$ (SE)	$\beta$ (SE)	$\beta$ (SE)	$\beta$ (SE)
Intercept $\beta_0$	21.43 (3.06)***	45.74 (4.91)***	43.18 (2.01)***	28.48 (2.22)***	53.84 (.69)***
Linear Slope $\beta_1$	-1.89 (1.57)	3.84 (1.58)**	1.90 (1.01)	-6.87 (.79)***	-.25 (.30)
Quadratic Slope $\beta_2$	-.18 (.15)	-.65 (.16)***	.22 (.11) <sup>+</sup>	-.48 (.09)***	-.01 (.03)
Class size (N (%))	62 (3.4%)	65 (3.7%)	312 (17.6%)	107 (6.0%)	1231 (69.3%)
Partnered (N (%))	35 (56.5%)	31 (47.7%)	177 (56.7%)	68 (63.6%)	683 (55.5%)
Post-school education (N (%))	2 (3.2%)	7 (10.8%)	51 (16.4)	14 (13.1%)	245 (19.9%)
Baseline Age (M (SD))	66.21 (10.79)	66.85 (10.25)	68.87 (9.08)	69.03 (8.41)	69.91 (7.64)
Vitality Intercept (M (SD))	36.87 (2.44)	42.45 (4.98)	40.49 (4.54)	40.50 (6.24)	45.57 (6.03)
Vitality Slope (M (SD))	.65 (1.18)	-.98 (1.83)	-.64 (1.41)	-2.15 (2.14)	-1.67 (1.35)
Physical Health Intercept (M (SD))	39.70 (4.84)	43.05 (7.35)	41.57 (6.64)	41.91 (7.19)	43.96 (7.53)
Physical Health Slope (M (SD))	-.83 (1.44)	-1.78 (2.12)	-1.38 (1.92)	-2.09 (2.34)	-1.77 (2.02)

\*\*\*  $p < .001$  \*\*  $p < .01$  \*  $p < .05$ ; <sup>+</sup> effect was significant with an alpha of .046 which only just reaches statistical significant ( $p < .05$ ) and is not of substantive size in comparison with the slope effects for those in the Improver (Class 2) or Terminal Drop (Class 4) classes.

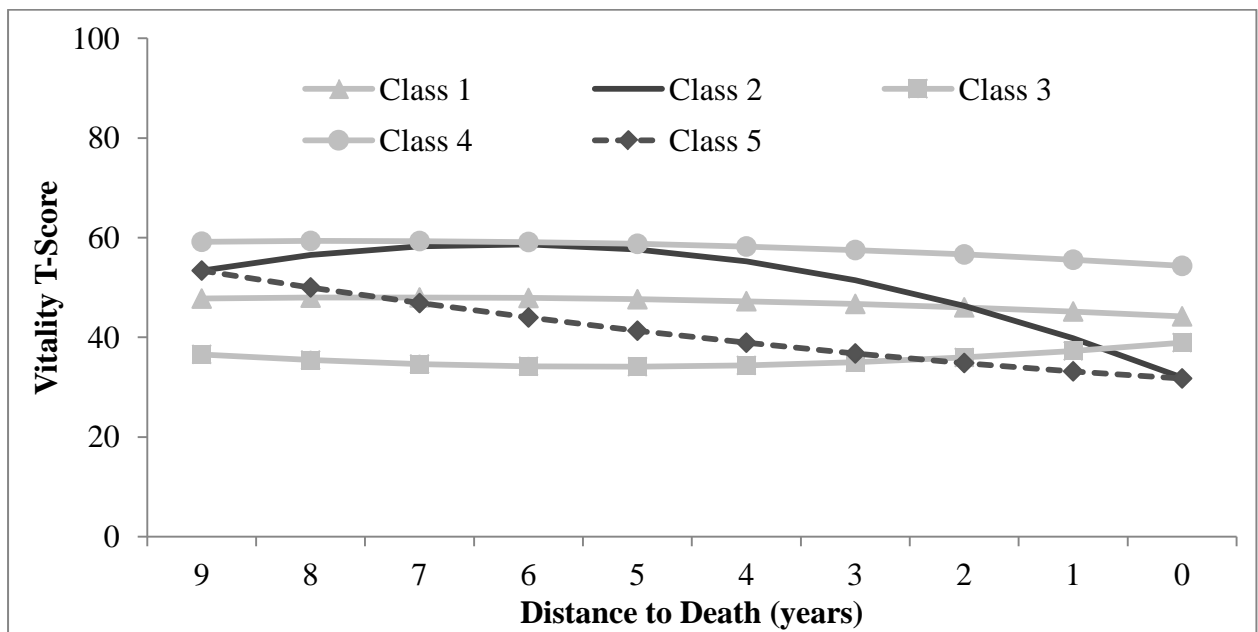
CONFIDENTIAL

Table 3 *Socio-demographic characteristics and Fixed Effects for vitality trajectories by mixture class*

	Class 1:	Class 2:	Class 3:	Class 4:	Class 5:
	Stable - Average	Terminal Drop	Stable - Low	Stable – High	Terminal Decline
	$\beta$ (SE)	$\beta$ (SE)	$\beta$ (SE)	$\beta$ (SE)	$\beta$ (SE)
Intercept	44.21 (1.50)***	31.91 (2.00)***	38.94 (1.53)***	55.85 (.98)***	31.75 (1.99)***
Linear Slope	-1.05 (.74)	-8.59 (.84)***	1.85 (.76)*	-.50 (.10)**	-2.38 (.241)***
Quadratic Slope	-.07 (.08)	-.69 (.09)***	.18 (.08)*	-.09 (.05)	.12 (.15)
Class size (N (%))	823 (46.3%)	72 (4.5%)	235 (13.2%)	524 (29.5%)	123 (6.9)
Partnered (N (%))	386 (46.9%)	31 (43.1%)	99 (42.1%)	219 (41.8%)	48 (39.0%)
Post-school education (N (%))	150 (18.2%)	17 (23.6%)	32 (13.6%)	105 (20.0%)	15 (12.2%)
Baseline Age (M (SD))	69.92 (7.70)	67.26 (10.01)	68.17 (9.34)	69.47 (8.24)	69.74 (7.78)
Mental Health Intercept (M (SD))	47.98 (6.88)	47.94 (8.96)	40.77 (10.58)	52.36 (5.02)	42.07 (9.61)
Mental Health Slope (M (SD))	-.83 (1.27)	-1.61 (2.22)	-.56 (1.47)	-.73 (.92)	-1.30 (2.30)
Physical Health Intercept (M (SD))	41.55 (5.81)	39.54 (4.61)	38.23 (4.94)	49.73 (6.90)	38.58 (32.24)
Physical Health Slope (M (SD))	-1.56 (2.02)	-4.59 (2.45)	-.54 (1.36)	-2.19 (1.70)	-.92 (1.81)

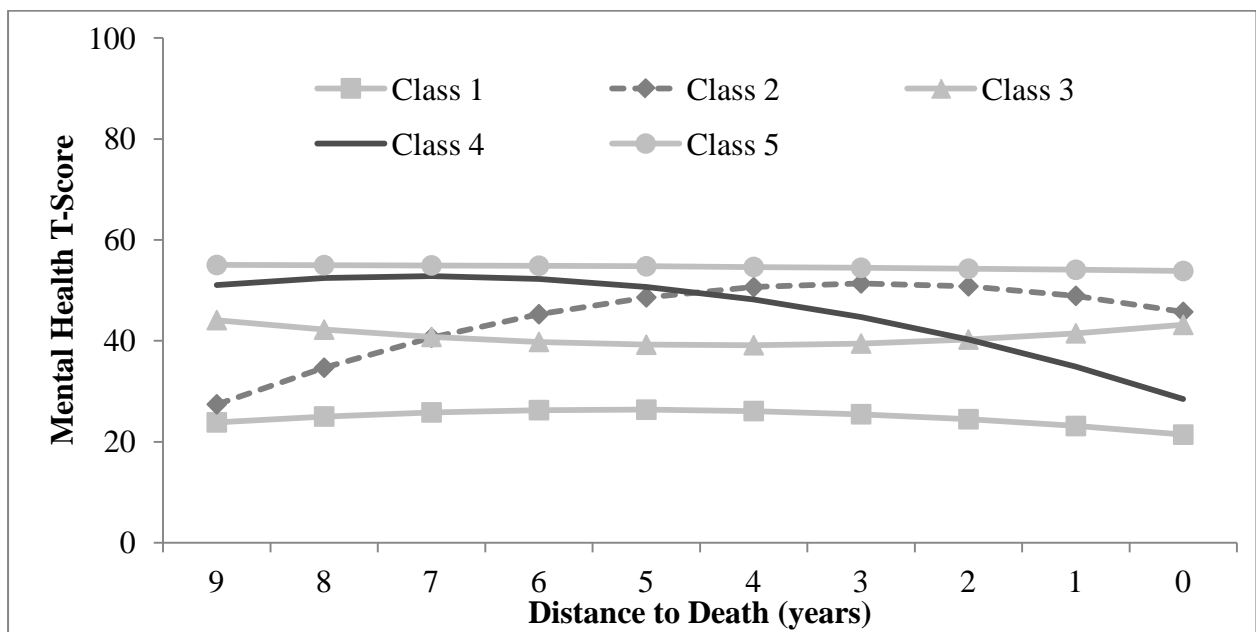
\*\*\* p < .001 \*\* p < .01 \* p < .05

Figure 1 Classes of Vitality Trajectories



CONFIDENTIAL

Figure 2 Classes of Mental Health Trajectories



CONFIDENTIAL

CONFIDENTIAL