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VANGUARDS OF LONGEVITY: THE CASE OF BRAZILIAN AIR FORCE MILITARY

Vanessa Gabrielle di Lego Gonçalves

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Vanguards of Longevity: The case of Brazilian Air Force military

Vanessa Gabrielle di Lego Gonçalves

Tese submetida à banca examinadora designada pelo Colegiado do Programa de Pós-Graduação em Demografia da Universidade Federal de Minas Gerais, como parte dos requisitos necessários à obtenção do grau de Doutora em Demografia.

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Abstract

In the demographic study of mortality, there has been growing attention to population subgroups that are more likely to first benefit from mortality progress or benefit more intensively than others. Some authors define these subgroups as "vanguard" populations (Evgueni et al. 2014; Caselli and Luy 2014). Focusing on mortality trajectories of vanguard populations can be instrumental to disentangling the pathways to longer lives and isolating specific risk factors (Evgueni et al. 2014; Caselli and Luy 2014). Hence, we use a novel longitudinal military dataset for Brazilian Air Force personnel (BAF), considering them as a vanguard population subgroup in Brazil to explore two main questions: 1. Given a highly selected (vanguard) population subgroup in a developing country, what is the degree of survival selection among its members and what are the factors associated to it? 2. Are there other possible candidates as vanguard groups in Brazil? What is the true advantage of the military compared to other low mortality subgroups? Our sample is composed of $N = 13,341$ individuals, comprised of $D = 3,084$ deaths (23.11% of total sample) and $S = 10,257$ survivors. We employ non-parametric (KM curves) and semi-parametric (Cox regression) approaches to address question number 1, and compute probabilities of death by single ages derived from the incidence rates to compare with other vanguard population groups in Brazil and address question number 2. We show that even in a selected setting place of birth and educational background are still important to explain mortality differenetials, suggesting "scarring" effect among the BAF personnel.

Key-words: Vanguard; BAF military; Adult Mortality; Longevity; Selection

Resumo

No estudo demográfico da mortalidade, mais atenção tem sido dada a subgrupos da população que se beneficiam primeiro ou mais intensamente dos progressos em mortalidade. Alguns autores definem esses subgrupos como populações de "vanguarda" (Evgueni et al., 2014, Caselli e Luy, 2014). Concentrar-se nas trajetórias de mortalidade das populações de vanguarda pode ser uma estratégia para melhor compreender os mecanismos que levam à vida mais longa e isolar fatores de risco específicos (Evgueni et al., 2014; Caselli e Luy, 2014). Com isso, fazemos uso de um novo banco de dados longitudinal de militares da Força Aérea Brasileira (FAB), considerando-os enquanto uma população de vanguarda, para examinar duas questões principais: 1. Dado um subgrupo de população altamente selecionado (vanguarda) em um país em desenvolvimento, qual é o grau de seleção de sobrevivência entre seus membros e quais são os fatores associados a ele? 2. Existem outros possíveis candidatos como grupos de vanguarda no Brasil? Qual é a verdadeira vantagem dos militares em comparação com outros subgrupos de baixa mortalidade? Nossa amostra é composta de $N = 13,341$ indivíduos, incluindo $D = 3,084$ mortes (23,11% da amostra total) e $S = 10,257$ sobreviventes. Nós empregamos abordagens não-paramétricas (curvas KM) e semi-paramétricas (regressão Cox) para tratar da nossa primeira questão e estimamos probabilidades de morte derivadas das incidências de morte para responder à questão número 2. Mostramos que, em um cenário selecionado, o local de nascimento e os antecedentes educacionais ainda são importantes para explicar os diferenciais de mortalidade, sugerindo um efeito de "scarring" entre militares da FAB.

Palavras-chave: Vanguarda; FAB; Mortalidade adulta; Longevidade; Seleção

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Ao Vitor, minha alma gêmea.

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1 Introduction

In the demographic study of mortality, there has been growing attention to population subgroups that are more likely to first benefit from mortality progress or benefit more intensively than others. Some authors define these subgroups as “vanguard” populations and the reasons for the increased interest in these groups are threefold. First, mortality trajectories of vanguard populations can be instrumental to disentangling the pathways to longer lives and isolating specific risk factors (Evgueni et al. 2014; Caselli and Luy 2014). In addition, the survival advantage of these selected groups can help reveal the distribution of mortality gains within and between countries at different stages of the health transition. This seems to be particularly important in a context of increasing mortality differentials not only across countries, but also at the sub-populational level that has characterized the second half of the 20th century (Mackenbach 2003; Andreev et al. 2011; Caselli, Meslé, and Vallin 2002; McMichael et al. 2004; Moser, Shkolnikov, and Leon 2005). Third, there is growing availability of high-quality mortality data for vanguard groups, including in middle-income economies, which has offered the opportunity of novel survival analyses in different socioeconomic contexts (Lego, Turra, and Cesar 2017).

This approach has led researchers to concentrate on different vanguard segments of the population, depending on the context of study. One the one hand, some scholars explore broader subnational groups, such as the work by Evgueni et al. (2014), which defines as vanguard the married and highly educated within three nordic countries: Finland, Denmark and Sweden. By comparing trends in life expectancy at age 40 and mortality by cause of death between the vanguard group and the rest of the population from the 1970s to 1990s, the authors show no sign of convergence between the higher and lower mortality groups, indicating that vanguard and non-vanguard have their own pathways to transition to lower mortality schedules. This result provides evidence that laggards will not necessarily follow the forerunner´s path to lower mortality as the demographic transition unfolds within a given population or thereafter, even when considering more egalitarian countries that have developed welfare state systems. On the other hand, some studies have examined the survival advantages or disadvantages of subgroups that represent small but selected fractions of the population, as a means of isolating specific risk factors, since those subgroups tend to be more selective and homogenous, with less confounding elements coming into play. Those groups include certain learned societies (Andreev et al. 2011; Winkler-Dworak and Kaden 2014), master athletes (Lemez and Baker 2015; Teramoto and Bungum 2010), religious groups (Enstrom and Breslow 2008a; McCullough et al. 2000; Luy, Flandorfer, and Di Giulio 2015; Luy 2003), and the military (Costa 2012; Costa 2003; Costa and Kahn 2010). However, work on military mortality has been more often developed by those who are interested in survival under extreme conditions, such as war and famine, as well as on the mechanisms responsible for mortality differentials over the life cycle. But in countries that have not been involved in important internal conflicts or foreign wars, the military live in favorable conditions, with officers being positively selected in terms of survival. In such cases, they usually experience higher life expectancies than their national counterparts, both in developed (Besco et al. 1995; Inskip, Snee, and Styles 1997) and developing contexts (Lego, Turra, and Cesar 2017). Besides, the military undergo specific training that seek to standardize their professional pathways, providing them with similar experiences of socialization, as well as "the same institutional rites and career turning point" (Castro 2000). The effort of the military schools and academies is to standardize their behavior, in order to enable them to cope with the demanding expectation of the military service, especially in stressful situations. Hence, the military in Brazil can be an insightful subgroup to analyze, since they combine both the homogeneity aspect that may enable the isolation of specific risk factors, and the vanguard aspect of experiencing a survival advantage relative to their national counterparts (Lego, Turra, and Cesar 2017). In this present study, we are particularly interested in analyzing if different backgrounds before their enrollment in the institution affect their survival throughout their lifetime, as well as how do the differentials operate in such a selective setting. Taken all those aspects into consideration, coupled with the fact that in developing countries there is often little or inaccurate information on gradients in mortality (Turra, Renteria, and Guimaraes 2016; Silva, Freire, and Pereira 2016), the military may help improve our understanding of mortality gradients and the gap between the average population and a vanguard subgroup.

1.1 Research Questions

Motivated by the vanguard approach, this work addresses the following two main question:

1. Given a highly selected (vanguard) population subgroup in a developing country, what is the degree of survival selection among its members and what are the factors associated to it?
2. What are the other possible candidates as vanguard groups in Brazil? What is the advantage of the military compared to other low mortality subgroups?

In order to explore this set of questions, we use a novel longitudinal military dataset for Brazilian Air Force personnel (BAF) individuals who entered the institution from 1943 to 2000 and were followed until 2015. For the begining of our analysis, we first use data from the Human Mortality Database (Sweden, years 1940-2010/Japan, years 1947-2010) and UN Brazilian and Chilean life tables (years 1950-2010),in order to set the scene of BAF's advantage compared to low mortality countries and their national/neighboring counterparts. Next, we employ a survival approach to estimate the effects of prior educational level, place of birth, career path and birth cohort on overall survival of BAF males, to address our first research question. Lastly, to address our second question, we use other available data on subgroups that experience lower mortality, such as the recently developed life tables for insured Brazilian lives (year 2010) and the executive branch federal civil servant (De Oliveira et al. 2016; Beltrão and Sugahara 2017). We also use the Retirement Plans Experience Committee of the Society of Actuaries (SOA-USA) life tables, because they are used by the actuaries in the Brazilian Armed Forces in order to estimate pension benefits (DoD 2016).

1.2 Motivation: Why the military?

It has been shown by many studies that the military present an important survival advantage relative to their national counterparts, even in extremely stressful contexts (Costa2012; Horiuchi 1983; Buzzell and Preston 2007; McLaughlin2008a; Shah 2009).

Their advantage stems from strict physical criteria for recruitment, a requirement to maintain a certain standard of physical well-being, and better access to medical care during military service (Kang and Bullman 1996). However, studies that use military data usually employ a life cycle approach to assess the consequences of physical and cognitive hardship on later mortality and morbidity (Fogel and Costa 1997; Costa 2012). In our study, we seek to focus on the military as a vanguard population subgroup, as a means of isolating specific risk factors, since those subgroups tend to be more selective and homogenous, with less confounding elements coming into play.

Specifically in the Brazilian case, there are three main demographic and epidemiological advantages and strengths of using this type of data to study mortality. First and most importantly: it is a novel retrospective longitudinal database, where we can track each individual until their moment of death or end of follow-up, allowing for inter and intra-cohort analysis. Despite a lot of effort in developing longitudinal databases that focus on health and mortality outcomes in Brazil, they are still time-consuming and expensive, and demand persistent funding sources. It was only until very recently that the Brazilian Ministry of Health acknowledged the importance of long-term funding to national research, resulting in 2008 on the emergence of the largest prospective cohort study on chronic diseases in the country: The Brazilian Longitudinal Study of Adult Health (ELSA-Brasil)(Aquino et al. 2012). However, ELSA's focus is on the development and progression of clinical and subclinical chronic diseases, particularly cardiovascular diseases and diabetes, and it is also a relatively recent research design (baseline year 2008). There is also ELSI-Brasil (The Brazilian Longitudinal Study of Ageing), a longitudinal and nationally representative survey of older adults (aged 50 years and older) in Brazil that started in 2015 and which is still in its first wave of data collection. Despite the undeniable importance of tackling the impact of those diseases on overall health, and on the older adults, it does not allow us to investigate trends in mortality experiences yet. Second, due to the relatively wide timeframe of the database (1943-2015), it is possible to perform historical analysis that accounts for the impact of different birth cohorts on mortality. Third, the tradition of the military in keeping records updated and accurate makes it a very valuable and reliable database in terms of its register system, particulary when compared to other vital registration data in Brazil where accurate data to measure mortality patterns among population subgroups are usually lacking (Nepomuceno and Turra 2016; Lima and Queiroz 2014). Additionally, this longitudinal database has no lost to follow-up and the right-censoring is only due to administrative purposes (end of period study). We will further define in the Methods section the precise time frame we are going to employ for the specific research questions in this work. A fourth and more conceptual advantage that underlies most of this work is the fact that we are dealing with a highly selected population subgroup, which can provide interesting insights to mortality studies.

Taken all those aspects together, this dataset is particularly interesting to improve our understanding of male mortality within a developing country context that lacks good-quality, longitudinal and long-span vital information. Adopting the military as a vanguard subgroup in Brazil may help reveal the whereabouts of the upper limits of mortality gradients, the impact of background on mortality, and the gap between the most and the less advantaged groups of the population.

1.3 Structure

For the sake of analysis, we have structured this dissertation into five Chapters: this first Chapter introduces the research objectives and motivation to the reader. The following Chapter focuses on the background literature that support our two research questions. Chapter 3 presents the material and methods employed, with a particular focus on the military database to familiarize the reader with the characteristics of this unique information set. Chapter 4 presents the results, discussing each of the proposed research questions. The final and fifth Chapter connects all the results achieved and discusses a new framework for approaching mortality. We also present an overview of future research and the applications of our results and the proposed framework.

2 Background

2.1 Survival advantages in specific subgroups: outlining the concept of vanguard population

Research in the mortality field has been increasingly focusing its attention on survival advantages among specific population subgroups. The interest in acknowledging mortality differentials within a given population is not new and advantages associated to higher income, higher educational attainment (Preston and Elo 1995b), better occupational status (Cutler, Lleras-Muney, and Vogl 2008), gender (Crimmins and Saito 2001; Case and Paxson 2005; Norris and Nissenson 2008), race (Preston, Hill, and Drevenstedt 1998a; Williams 2012) and marital status (Smith, Zick, and Duncan 1991; Goldman 1993; Waite and Gallagher 2000) have been widely documented. However, due to the wide array of confounding factors and pathways that link specific risk factors to mortality, it is very difficult to isolate a single factor and estimate how much life expectancy differentials are specifically atributable to education, income, gender, race, or marital status alone (Caselli and Luy 2014). In addition, due to the particularities of social science research and the complexity of human phenomena, we cannot design laboratorial research where we can test factors in controlled settings. This context has motivated researchers to look for specific selected advantageous sub-populations in which risk factors are more easily isolated, mainly due to their homogeneity or paradoxical outcomes, including resilience to negative habits (Levine and Crimmins 2014), certain learned societies(Winkler-Dworak and Kaden 2014; Andreev et al. 2011), migrants (Turra and Goldman 2007; Razum and Twardella 2002), religious groups (Enstrom and Breslow 2008b; McCullough et al. 2000; Luy, Flandorfer, and Di Giulio 2015; Luy 2003), athletes (Lemez and Baker 2015; Teramoto and Bungum 2010), and the military (Costa 2012; Costa 2003; Costa and Kahn 2010).

Winkler-Dworak and Kaden (2014) estimated that academicians of the Saxonian Academy of Sciences in Leipzig can expect to live at age 60 seven years more than the average German male. In addition, it has also been shown that the members of the Austrian and the Russian Academy of Sciences have lower mortality than the population with tertiary education in their respective countries (Winkler-Dworak 2008). The explanations for longer lives among the learned societies include higher socioeconomic and educational levels since childhood, access to health care (Andreev et al. 2011) and psycho-social factors, such as autonomy, active cognitive reasoning and control at work and in life (Marmot et al. 1998). Scholars have also examined mortality differentials among religious groups. Enstrom and Breslow (2008b) showed that Mormon males can expect to live 9.8 years more than U.S. white males for periods 1989-1991, whereas females had a life expectancy of 86.1, about 5.6 years greater than U.S. white females in 1989-1991. Among the explanations for the mortality advantage of Mormons is the adoption of healthy lifestyles including the abstention from alcohol, tobacco and stimulating drinks, such as coffee or tea, and the use of a balanced diet. Other religious groups that value healthy lifestyles, like Seventh-Day Adventists, also have substantially reduced mortality rates when compared to their peers (Hummer et al. 1999; McCullough et al. 2000). Mortality advantages among Hispanics, relative to non-Hispanic whites in the U.S., have also being widely reported, despite their lower socio-economic status (Palloni and Morenoff 2006). Several factors are associated with the lower mortality among Hispanics including the selection of healthy immigrants (Turra and Goldman 2007), selective return migration (Abraído-Lanza et al. 1999), data problems (Markides and Eschbach 2005; Palloni and Arias 2004), as well as cultural, neighborhood, and behavioral factors (Eschbach et al. 2004). More recent work on the topic examines if the Hispanic mortality paradox is also translated into a Hispanic disability paradox. Authors show, however, that disability rates are substantially higher for Hispanics than non-Hispanic whites and generally similar to those of non-Hispanic blacks, indicating that mortality advantage may not mean health advantage (Hayward et al. 2014). The mortality advantage of foreign-born groups are not limited to the U.S. and have been reported in Europe as well, including among the Turkish in German, Mediterranean in France, and other immigrants in Canada (Razum and Twardella 2002; Khlat and Darmon 2003; McDonald and Kennedy 2004). Resilience to risk factors, such as the case of long-lived smokers, is also studied by some scholars as a means of improving understanding on biological factors that are difficult to isolate or measure, such as underlying innate frailty (Levine and Crimmins 2014). In this previous work, the authors show that smoking did not significantly contribute to the risk of mortality once you focus on the subgroup of smokers who are aged 80 and over. In a sense, this group appears to have a distinct and biologically advantaged body metabolism, making it an interesting case to attempt at assessing biological or genetical factors associated to mortality risk. Following the same line of reasoning, some research focus on the cloistered populations of monks and nuns, where the results show their important survival advantage over the German population. In addition, since they live under similar environmental conditions, they provide a near-perfect sample to try to understand the biological versus environmental factors in life expectancy (Luy 2003; Luy, Flandorfer, and Di Giulio 2015). All the aforementioned subgroups can be considered as extreme examples of vanguards of longevity, if we accept the definition of vanguard population proposed by Evgueni et al. (2014), in which some groups benefit first or more intensively than their peers of comparable age and period from mortality progress.

2.2 Survival advantages in the military

Although it is reasonable to assume that members of the military are healthier than the average citizen, it is still somewhat surprising that they experience lower mortality than most groups in society, even in the context of extreme settings such as famine (Costa 2012; Horiuchi 1983), and war (Buzzell and Preston 2007). Buzzell and Preston (2007) estimated the death rates of United States troops in Iraq since the beginning of the U.S invasion. According to the authors, death rates for black males aged 20-34 in 2002 living in Philadelphia were 9% higher than for troops in combat in Iraq. A much earlier work from MacIntyre et al. (1978), which followed the U.S Navy's cohort of 800 survivors from World War II and the Korean conflict, showed that pilots experienced not only lower all-cause mortality, but also lower mortality from cardiovascular, cancer, and accidental causes when compared to the U.S civilian population. The main explanation, according to the author, was the generally good socioeconomic background of members of the military. He also speculated about the positive genetic influence of long-lived parents, above average intelligence, and the health and fitness orientation of the military aviators (MacIntyre et al. 1978). Some scholars have argued that the survival advantage of the military accrues from a selection bias at enlistment or recruitment, sometimes called the "healthy soldier effect" (McLaughlin, Nielsen, and Waller 2008; Shah 2009), in which the selection of the healthier and fitter results in lower mortality rates. Variations in risk of death among the military officers, particularly during times of war, reflect several underlying factors, including military branch and service component, as well as rank in service. Buzzell and Preston (2007) showed that these characteristics affect exposure to combat and therefore, the variability of mortality risk across subgroups. Other work has used military data to approach epidemiologically the pathways through which more risky and stressful situations affect survival and causes of death within a life cycle perspective. Models of mortality selection posit that insults at younger ages can yield individuals that are more robust at older ages (Horiuchi and Wilmoth 1998; Manton and Stallard 1981; Preston et al. 1996). However, there is also evidence of positive associations between hazardous life events and morbidity and mortality later in life (Finch 2004; Horiuchi 1983; Kannisto, Christensen, and Vaupel 1997; Preston et al. 1996). Recent research evidenced that veterans from the American Civil War who experienced greater stress in battle had higher mortality rates at older ages and were at greater risk of developing Post-Traumatic Stress Disorder (PTSD) (Costa and Kahn 2010). Other work on PTSD show that exposure to military trauma can impact physical health in later years among veterans both in the U.S and Europe (Clipp and Elder 1996; Elder et al. 2009; Chatterjee et al. 2009). Some scholars have also taken advantage of military data to explore the relationship between nutritional status and exposure to infections earlier in life with subsequent mortality levels (Fogel and Costa 1997). Costa (2003) found that stomach ailments while in the army significantly predicted mortality from all causes, and from some specific chronic diseases. Respiratory infection, for example, significantly predicted mortality from respiratory illnesses and acute illnesses, when other wartime disease covariates were excluded (Costa 2003). In another set of studies, Fogel and Costa (1997) used data on Civil War soldiers to show that poor body builds increase vulnerability to both contagious and chronic diseases, and can be powerfully predictive of morbidity and mortality at later ages (Fogel and Costa 1997; Costa 2012).

Another important line of research places military survival advantage within the occupational literature. This perspective focuses on military as an occupation among others, and thus also include analysis from military at peace times. In this case, the framework is that of the healthy worker effect, i.e., fact that workers have lower death rates than the general population, since good health is related to the ability of securing and maintaining employment, while the general population includes sick and disabled people who may be at greater risk of dying (Choi and Noseworthy 1992; Goldsmith 1975; Shah 2009). The military occupation is a specific case of this phenomenon, where individuals experience an even higher degree of selection, coined in the literature as the "healthy soldier effect" (Guest and Venn 1992; Kang and Bullman 1996; McLaughlin, Nielsen, and Waller 2008). Kang and Bullman (1996) showed that strict physical criteria for recruitment, a requirement to maintain a certain standard of physical well-being, and better access to medical care during military service explain the lower mortality among military personnel relative to the general population. McLaughlin, Nielsen, and Waller (2008) summarized the evidence comparing mortality rates of military personnel with the general population and quantified the magnitude of the healthy soldier effect focusing on nineteen primary studies that investigated the association between service in the military and mortality rates. They showed that most studies presented standardized mortality ratios (SMR) less than 1, indicating that military populations had lower all-cause mortality than the general population. A study that focused only on US retired civil airline pilots during years 1980-1989 also showed that their life expectancy was 5 years higher than the average white male, suggesting that not only military pilots, but also civil aviators, present a survival advantage relative to their national counterparts (Besco et al. 1995). However, evidence also supports that within the military, groups belonging to lower stratum, experience an even higher mortality than the general population (Coggon and Wield 1993). Coggon and Wield (1993) showed that military cooks and pay clerks presented higher all-cause mortality than the general population, indicating that the healthy soldier effect is not applicable to all military rank or career types. Other evidence stress the importance of the contribution of external deaths on the overall rates for military officials (Inskip, Snee, and Styles 1997; McLaughlin, Nielsen, and Waller 2008). Inskip, Snee, and Styles (1997) shows that submariners in the Royal Navy presented a SMR of 115 due to external deaths and at younger adult ages (25-35), relative to the general British population, also supporting that deaths due to external causes are not trivial in the military population. Hence, despite the acknowledged survival advantage of this subgroup, mortality differentials due to both background and occupational characteristics exist.

2.3 The influence of background on mortality

Many of the authors we have cited emphasize the importance of background in explaining mortality differentials among the long-lived, especially educational attainment. Winkler-Dworak and Kaden (2014) mentions that the higher level of education explains the survival advantage among the members of the Austrian Academy of Sciences, which were immune even to the strong impact of the East/West divide in Germany during WWII on mortality levels. Kang and Bullman (1996) also atributes to education and health access the lower mortality among military, and Evgueni et al. (2014) use the highly educated as a subgroup of vanguard population in nordic countries. The association between education and mortality happens through many pathways and has been widely debated. The earlier work of Feldman et al. (1989) already showed that since 1960 death rates among males were declining more rapidly for the more educated than the less educated in the U.S. Along that line, Preston and Elo (1995b) evaluated the quality of the U.S 1960 baseline estimates and showed that educational inequalities widened for males, but not not for females. Other authors aimed at analyzing more closely the shape of the association between educational attainment and adult mortality in the U.S, showing an important and widening mortality differential between the higher and lower educated Americans, throughout the 21st Century (Mark D Hayward, Hummer, and Sasson 2015). Likewise, Lleras-Muney (2005) used successive U.S censuses to estimate the impact of educational attainment on mortality rates, and concluded that education has in fact a causal impact on mortality. Work that focused on the translation of educational improvement into lower mortality and better health by gender showed that educational gains have a larger effect on female self-rated health than on males. However, since females tend to report worse health at the same time that male mortality is higher, the gender gap in both health and mortality tend to be insignificant (Ross, Masters, and Hummer 2012). More recent work has explored the intergenerational effect of higher education, showing that children who were born to the most-educated women are gaining resources and improving in life, while those who were born to the least-educated women are losing resources, which could potentially affect mortality and health differentials on the long-run (McLanahan 2004). Other research claims that educational background is so important that it should be considered a demographic component together with mortality, fertility and migration, taking part inclusively in setting parameters of projection scenarios (Lutz and KC 2011). For developing country contexts such as the Brazilian one, mother's education has been shown to be a key factor underlying childhood mortality (Sastry 2004), while other authors highlight the relationship between educational levels and health outcomes associated to high fatality, such as the increased risk of lung cancer among the higher educated (Bouchardy et al. 1993). Nonetheless, the amount of work that seeks to address the relationship between educational attainment and adult mortality in Brazil is still very scant. One challenging aspect that prevents researchers from appropriately tackling this issue is related to the unreliability of death registers according to educational levels, leading to imprecise estimates. Recent effort to overcome this problem and address the relationship between adult mortality and educational composition change in population stated that death records miss almost one third of the education information of the deceased (Turra, Renteria, and Guimaraes 2016). The same study showed that 35% of adult lives spared in Brazil between 1960-2010 are attributable to composition changes in the educated population alone. The more recent work of Martins Ribeiro (2016) aimed at overcoming data limitation with imputation approach applied to the Brazilian Census. The author showed a significant educational gradient in mortality, especially for males in a developed region in Brazil, the city of São Paulo, as compared to the rest of the state. Interestingly, the authors also show that the differences in mortality by educational level were constant with age, while the literature predicts that these differentials should be decreasing. Hence, we take advantage of having reliable information on the last educational level attained for this set of military personnel to address whether educational background affects survival, net of other characteristics that we observed, as well as to provide an estimate of mortality rates by level of education. Since the military environment is very controlled and specific, we aim at analyzing if educational attainment prior to enrollment in the institution has any effect on their survival.

In addition to the importance of education, another debated variable is place of birth or household status (e.g., rural/urban) as a proxy for childhood conditions and/or background information. We use place of birth as another background indicator among the military, accounting for the different levels of regional development in Brazil. One should note that the demographic transition has been operating at its full force in Brazil since the 1940s, and it has certainly affected the chances of survival of our sample. Life expectancy at birth rose from 45.5 years in 1950 to 70.4 in year 2000, mainly because of a dramatic decline in infant mortality rates (Vasconcelos and Gomes 2012), although there have been survival gains across all ages groups. Due to its vast territory and different regional development, Brazil's epidemiological and demographic transitions have been not only fast-paced, but also happened at different levels and timings throughout the country, revealing its regional disparities. For instance, infant mortality rate in the southern area of Brazil declined from 81.9 in 1970 to 16.9 per thousand live births in 2000. In the northeast, the rate was about 146.40 per thousand in 1970, and despite its substantial decline, remained at a significantly higher level than the south in 2000 (38.4

per thousand) (Vasconcelos and Gomes 2012). We categorized place of birth according to more and less developed regions in Brazil so as to capture if there is any effect of those variables on overall survival. We employ this categorization in order to test whether there is any difference in survival when comparing more and less developed places of birth. In addition, the number of cases for precisely each region in Brazil was insufficient and so we grouped them into two main broad regions of development: southern and northern. Since the levels of development between those two regions is very different, we seek to capture possible inequalities in survival with this categorization. The literature provide evidence of both negative or positive association between childhood conditions and later survival. According to Preston, Hill, and Drevenstedt (1998b), childhood conditions may influence adult mortality through a physiological, direct mechanism or through a non-physiological, indirect mechanism. These two mechanisms may also be positive or negative. A direct and positive effect is one that has a permanent impact or a scarring effect that influences later health and survival, for example, the influence of having tuberculosis in childhood and higher mortality at later ages. An indirect and negative effect, on the other hand, is acquiring immunity due to exposure to certain diseases in childhood and presenting lower mortality afterward. Along that line, some authors show strong associations between early-age mortality and subsequent mortality in the same cohorts, suggesting that inflammatory processes that are present at early ages may persist into adult life and are not mitigated by other processess (Finch 2004). However, there is evidence in the literature that mid-life factors, such as behavior related to tobacco and alcohol abuse and sedentary life styles, may mitigate or intensify the influence of earlier life events on old age mortality, so it depends on the mid-life factors and on the timing of those mid-life interventions (Hayward and Gorman 2004; Raalte, Myrskylä, and Martikainen 2015).

Again, because BAF personnel are submitted to an extremely controlled environment that offers an overwhelmingly good health, nutritional and social support, we seek to address if those features offset the effect of being born in more or less developed regions, dealing with enrollment in the institution as a mid-life factor of life change event.

3 Material and Methods

3.1 Data

3.1.1 The Brazilian Air Force (BAF) database

The objective of this section is to present the dataset and its available variables. We retrieved data from the Brazilian Air Force military personnel information and health system (SIGPES/DIRSA), for males who entered the institution from 1943 to 2000. It is a retrospective longitudinal database where we can track individuals from enrollment in the military until death or last date of follow-up (December 3rd, 2015). Females are not included in the analysis because they engaged in the military institution much later than males, and also had recruitment criteria that changed over time, preventing us from performing a proper analysis and keeping control of data. In addition, information was limited to individuals who followed the military career throughout their entire professional lives. Therefore, soldiers and temporary officers who may abandon military life during active years and hence be missed in the system are not included. We also restricted the survival analysis window between ages 35 and 85 since information at older ages was less reliable and deaths before age 35 are concentrated at specific career types and associated to occupational risk, confounding the analysis, as we detail below. This left us with a total sample of $N = 13,341$ individuals, comprised of $D = 3,084$ deaths (23.11% of total sample) and $S = 10,257$ survivors.

Table 3.1 presents an overview of the available variables, together with a brief description, samples sizes and survival status until the last date of follow-up.

Table 3.1: Description of database, according to survival status and available variables

Variables		Characteristics	Sample size	Survivors	Deaths
			N=13,341	*S=10,257*	*D=3,084*
Career					
	Academy	primary or secondary educational level prior to military	4,672	3,771	901
	Tertiary	tertiary educational level prior to military training	2,641	2,104	537
	Secondary	secondary educational level prior to military training	6,028	4,382	1,646
Region					
	Northern	birth in the least developed regions in Brazil	4,682	3,140	1,542
	Southern	birthn in the most developed regions in Brazil	8,659	7,117	1,542
Birth Cohort					
	1900-1930	birth cohort between 1900-1930	1,822	661	1,161
	1930-1960	birth cohort between 1930-1960	8,910	7,096	1,814
	1960-1980	birth cohort between 1960-1980 (last birth year decade)	2,609	2,500	109
Age at entrance					
	15-20		8,044	6,581	1,463
	20-25		3,371	2,381	990

age at enrollment in the institution,
grouped in 5-year age intervals

Table 3.1 continued from previous page

Variables		Characteristics	Sample size	Survivors	Deaths
			N=13,341	*S=10,257*	*D=3,084*
	25-30		1,397	961	436
	30-35		409	273	136
	35-40		95	51	44
	40-45		25	10	15
Occupation, by career type					
Academy					
	Pilots	full military, flight training and management	3,172	2,540	632
	Infantry	full military, mainly operation and tactics training	478	375	103
	Intendant	full military, mainly administration training	1022	856	166
Tertiary					
	Higher rank	doctors/ Engineers with previous university level degree	1,360	1,090	270
	Lower rank	technical (e.g. air traffic control); services (e.g. dentists, religous ministers)	1,281	1,014	267
Secondary					
	Service	cleaning, cooking, house keeping	6,028	4,382	1,646

Table 3.1 continued from previous page

Variables	Characteristics	Sample size	Survivors	Deaths
		N=13,341	*S=10,257*	*D=3,084*

Source: SIGPES/DIRSA (2015)

In addition to those variables, we have complete dates of birth (DD-MM-YYYY), entry in the Air Force (DD-MM-YYYY), and death (DD-MM-YYYY). As stated in Table 3.1, we have grouped place of birth into the most and least developed regions in Brazil. The Northern region comprises persons who were born in the north, northeast and center-west regions. The Southern region includes south and southeast. In addition, birth cohorts were grouped into 3-decade intervals, with the exception of the last period that was grouped from 1960-1980 since 1980 was the last observable year of birth. As Table 3.2 further details, there are ranges of acceptable ages into the Air Force, depending on the career of choice. Hence, we also grouped ages at entrance into 5-year intervals. Lastly, we have three types of career available in this sample: Academy, Tertiary and Secondary. These were categorized according to the educational background required for enrollment in each career and according to the specificity of the core occupation in the Air Force, which are the Academy officers. Academy represent those individuals who enroll in the institution at very early ages and are heavily trained to become an officer. Tertiary are persons with an university level degree that later enroll in the institution through a selection process. Secondary are individuals with a high school degree who also enroll in the institution through a selection proccess. With this categorization, we seek to address the impact of coming from different educational backgrounds on overall mortality. In addition, within each career there are specific occupations; the Academy career is composed of Pilots, Intendants and Infantry. The Tertiary career is composed of higher and lower rank occupations, while Secondary is composed of service staff. The educational background is categorized following the International Standard Classification of Education (UNESCO 1997) and the Brazilian Laws that determine the level of educational attainment that is necessary to enroll in each specific career (Brasil 2011).

In Table 3.2, we provide a more in-depth look at the specific characteristics of the career types, with their respective occupations, and also the requirements to enter the miltiary institution according to the career of choice upon recruitment. The choice of career is fixed in time and cannot be changed throughout one´s life.

As previously noted, Academy officers are the ones with the longest military training and enroll at the youngest ages. While their initial training lasts up to 7 years, the other career types experience 17 weeks to 2 years of military training, depending on the occupation especificity. In addition, Academy officers not only receive military training,

Table 3.2: Description of career types and occupation, by enrollment requirements

Variables		Eligible Age (in years) for enrollment	Educational Requirement	Military training time
Career				
	Academy	14-23	Primary/ Secondary	4-7 years
	Tertiary	age limit 36*	University degree	17 weeks-2 years
	Secondary	17-25	High School	17 weeks-2 years

Occupation description, by career type

Academy		Activity	Last Attainable Rank (in Descending order)
	Pilots	flight and command	Air Chief Marshal**
	Intendant	administrative activities	Air Marshal
	Infantry	tactical operations	Air Vice Marshal
Tertiary			
	Higher rank	Doctor and Enginners	Air Marshal
	Lower rank	Technical and service support***	Colonel
Secondary			
	Service	Cleaning and cooking	Sub-officer

* Except for Religious ministers, whose age limit is 45
** This is the highest attainable rank in the Air Force and only pilots can reach this post
*** These are university level officers who offer specific technical or personal support, such as air traffic control, communication, dentists, aviation specialists and religious ministers.
Source: SIGPES/DIRSA 2015; Brazilian Law 12.464, 4 August 2011

but they actually got to school (secondary school for those who enter between ages 14-19) or to tertiary level education (for those who enter between ages 17-23 and already have secondary education) in the military institution. If they do not continue in the military careers, they receive a high school or an undergraduate diploma fully recognized by Brazilian's educational authorities (MEC). As for their occupational profile, they can enroll as either pilots, intendants or infantry members. Pilots are the ones with the riskier occupational profile, but also the ones with heavier military training and stricter physical and cognitive recruitment criteria. Intendants are administrative officers and infantry are tactics, intelligence and operational officers. As for the Tertiary career, there are higher and lower occupations. Higher refers to doctors and engineers. Lower refers to all other university level degree persons that will mainly work in the Air Force as a specialist in some field (e.g air traffic control and armory) or as support/service such as dentists, communication especialist/journalists, photography, religious ministers and others. Secondary refers to persons who have a high school/secondary education background and enroll in the Air Force to perform basic service activities, such as cleaning, cooking and organizing.

We did not use rank directly in our analysis as a covariate, due to their intrinsic time-varying characteristic and we did not have information on the time of promotions or changes in rank. However, they are useful concepts to understand the differences between the level of social status and also attainable incomes between career types and among occupations; they also imply different selection processes in the institution. For that reason we describe in Table 3.2 the highest attainable rank for each occupation within each career path. For instance, despite Tertiary career mean that an individual has previously undergone an university institution before enrolling the military, there are two different occupational paths, as previously noted: higher and lower. Higher tertiary means that doctors and engineers are considered as potential high-rank officers, and they are eligible to manage the institution. They can reach the rank of Air Marshal, which is only one rank below the highest attainable rank in the Air Force: Air Chief Marshal. Marshal means general, and it also means that an individual is apt to fulfill positions of command and high-stake responsability. On the other hand, lower tertiary can only go as high as Colonel, and, because they do not reach the general ranks, they are not apt for managing positions.

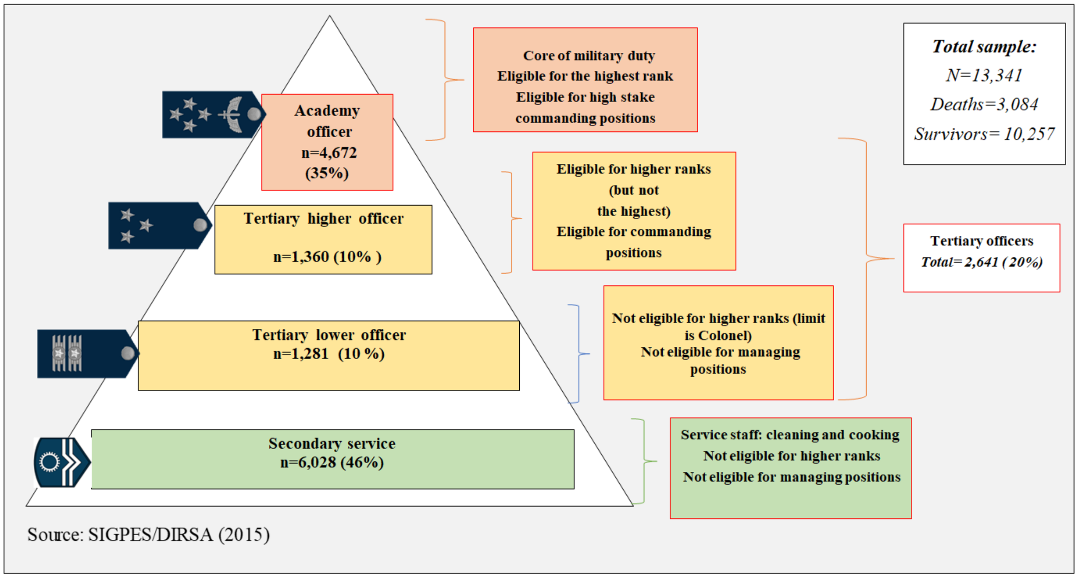
Pilots are the only ones allowed to reach the highest rank in the Air Force, followed by Intendants that reach the second highest rank and Infantry that can reach the third highest. They are all able to fullfill managing positions. They come from either primary or secondary educational backgrounds and are trained to make up the core of the institution. Secondary is composed of persons who have a high school/secondary education background and enroll in the Air Force to perform basic service activities, such as cleaning, cooking and organizing. Their highest attainable rank is sub-officer.

In order to highlight the military hierarchy of those career types and occupations, Figure 3.1 describes them in descending order. The pyramid aids in putting their hierarchical struture into perspective with the academy officers on the top of the pyramid and the service staff at the bottom. In the middle, we have the tertiary officers, which are divided into two categories that are also hierarchical: higher and lower.

3.1.1.1 Understanding the Selection Process

Here we further describe the differences in career paths and selection processes, since

Figure 3.1: Data characteristics, according to BAF hierarchical compositional structure



this provides us with a better understanding of how can survival differ among the career types. First, to become an Academy officer one must go through rigorous written and physical exams in order to enroll in military schools and academies (BAF 2014). The stages comprise: 1. Written exams (Math, Physics, Portuguese, English and Essay); 2. Psychological inspection; 3. Health inspection; 4. Physical Conditioning; and, exceptionally for pilots 5. Tests for measuring motor coordination specifically targeted at the ability to fly. With respect to the psychological criteria, they are mainly related to adaptation to extreme conditions without losing focus or logical reasoning, as well as organization, adoption of norms and cooperation skills. Regarding the health inspection, it includes complete blood tests, images of all bone structure of the body, teeth and gum health, anthropometric measures, circulatory exams, neurological exams, and hearing and sight tests (Brazil 1980). Candidates cannot have diabetes or other 189 diverse health related issues to enter the military career. Once approved in the written and physical exams, candidates go through an additional selection stage of a tough 40-day adaptation process (a military quarantine) composed of heavy military training. During the quarantine, they are not allowed to go home or go out, and communication with their families or friends is very restricted. If a candidate gives up within the first two weeks of the adapation process, there is a waiting list for a possible substitute. Only after this 40-day adaptation phase that candidates are officialy considered military cadets or students. During this time they are expected to not only receive military training, but also to internalize the military culture and moral values. As some authors point out, military education is oriented towards socializing the individual into a new cultural *ethos*, where a new identity is formed, linked to the military profession (Wortmeyer and Branco 2016). After the quarantine, their training lasts from 4 to 7 years, where they stil remain living in the institution during the week, but can now leave on weekends and holidays to see their families or go out. In summary, Academy officers have a more complete immersion in military life and culture, receiving full nutritional and physical support, wages, and daily military training starting at very young ages. The eligible age range for entering military school is from 14 to 19 years old (high school course), and for the military academy is from 17 to 23 years old (undergraduate course). Some individuals enroll directly in the military academy, while others first go to military school and then continue on the academy (Brasil 2011).

On the other hand, Tertiary officers undergo a much lesser strict military selection process. They have a previously attained university degree and apply for exams within their areas of specialization, such as engineering or doctors (higher tertiary) and other areas such as air traffic control, dentist, aviation, and religious ministers (lower tertiary). They take competitive exams to enroll in the institution, but the physical, cognitive and physchological requirements are less demanding. However, despite a less rigorous process, they also go through military training (depends on the field of specialization, but it can last from 17 weeks to 24 months) and undergo health screening (Brasil 2011). Hence, they are less immersed in military life, especially in the beginning of their careers, but they come from a higher educational background.

Lastly, for the secondary level the main eligibility criteria is to have secondary educational attainment. They are then trained to take part in the military service (which includes basic services such as cooking and cleaning). They are not considered officers, but have the right to retire and leave beneficiaries, and so also take part in the military pension fund system. They cannot move to the higher ranks in the military, stopping at the highest possible attainable rank of sub-officer. However, towards the end of their careers, they are eligible for some managing positions at the service branches, such as kitchen management and other services. They take many different courses throughout their careers related to organization, hygene food storage and kitchen management. Despite occupying a lower status position in the military pyramid, they also receive full access to health facilities and care (which extends to their families) and housing support.

These differences in educational background, occupational profile and military training are important to interpret the results and the differentials within this longevous group.

3.1.2 Other data

Besides focusing on our military components, we also use other data to perform estimates and comparisons. Table 3.3 ilustrates the type of data we used, the period to which they refer and the sources from where they were retrieved. We use the Combined Healthy Life Table (RP-2000), retrived from SOA, because it is the one employed by the Brazilian Air Force to estimate pension benefits. When then compare the estimates from this life table to our own in the last Chapter. Likewise, we perform other comparisons using the mortality experience of Brazilian's insured lives (BR-EMS 2010) and Brazilian's executive federal civil servants (Beltrão and Suahara 2017). We compare those life tables to our estimates of BAF mortality, in order to evaluate the possible difference between other subgroups in Brazil that also probably live longer to BAF's mortality experience. We also compare our estimates with Chilean males and average Brazilian males of the same period, in order to compare subgroup and overall survival in Brazil and in a Latin American country that is known for presenting lower male mortality rates.

Table 3.3: Data sources and description

Data	Period	Source
Age-specific mortality rates	1940-2010	Human mortality database (HMD)
Period Life table for Brazil and Chile	1950-2010	UN World Population Prospects
Combined healthy Life table (RP-2000 Rate)	2000	Society of Actuaries of America (SOA)
Brazilian insurance life table (BR-EMS 2010)	2010	Superintendencia de Seguros Privados
Brazilian Air Force	1943-2010	SIGPES/DIRSA
Brazilian executive federal civil servant mortality	1993-2014	Beltrao, K.;Suahara (2017)

Source: SIGPES/DIRSA 2015; SOA;Superintendencia de Seguros Privados
Beltrao, K.;Suahara (2017); HMD; UN World Population Prospects

3.2 Methods

3.2.1 Mortality rate updates

In order to place the mortality advantage of BAF military into perspective, we first estimate their mortality rates for the whole period available (1943-2010) by 5-year age groups, and compare with their Brazilian male counterparts and other low mortality countries (Sweden, Japan and Chile). We retrieved data from the Human Mortality database for estimating Sweden and Japan mortality rates and from the UN period life tables for Brazil and Chile for the same period. We chose Chilean males for performing comparisons because Chile is a country that is recognized for its lower male mortality and is a country with one of the highest life expectancy at birth in Latin America (84.5 for women and 78.6 for men)(United Nations Development Programme 2015). We summed deaths and person-years throughout the whole period for all countries and estimated an average mortality, in order to provide a first overarching picture. We computed the mortality rates from poisson regression, grouping deaths and person-years into 5-year intervals(Rodríguez 2007). In this first moment, rates were estimated from ages 15 to 80+, unsmoothed, in order to show a specific feature of BAF mortality curve. However, as we detail in the next methodological approach, our window of analysis will then be restricted to ages 35 and 85. We perform the statistical and graphical analysis in STATA and R.

3.2.2 Survival analysis

As a second step, in order to address the mortality differentials within the military, we employ a survival approach that appreciates the longitudinal character of this dataset. We first fit non-parametric survival curves to describe time until death according to different characteristics, followed by log-rank and peto tests to assess statistical significance among survival curves. Next, we fit Cox-Proportional Hazards models, which assume that there is a constant relationship between the outcome or the dependent variable and the covariate vector(Fox 2002; Geskus 2016; Kalbfleisch and Prentice 2002). The implications of this assumption are that the hazard functions for any two individuals or groups are proportional at any point in time and the hazard ratio does not vary with time, as shown in Equation 1:

$$h(t, X) = h_0(t) \exp\left(\sum_{i=1}^{p} \beta_i X_i\right) \tag{1}$$

Where $X = (X_1, X_2, X_3, ...X_p)$ represent the explanatory variables and h_0 is the baseline hazard. Since the baseline hazard h_0 is an unspecified function, this is a semi-parametric model with a baseline hazard that does not depend on the explanatory variables, but only on t (Kleinbaum and Klein 2011). The set of X are also time-independent. Additionally,

$$\exp\left(\sum_{i=1}^{p} \beta_i X_i\right) \tag{2}$$

is the relative risk, so that a proportionate increase or reduction in risk is the same at all durations t, which is why it is called a proportional hazards model. The estimated coefficients in the Cox proportional hazards regression model represent the change in the expected log of the hazard ratio relative to a one unit change in the considered predictor X_i, holding all other predictors constant, where the parameter vector β is estimated by maximizing the partial likelihood and possible tied event times in this dataset are handled using Efron approximation methods. However, since we have complete dates of events, ties are less of a problem. The proportionality in hazards are tested using the scaled Schoenfeld residuals(Fox 2002; Geskus 2016; Kalbfleisch and Prentice 2002). Deviations from proportionality are considered as $\beta_l(t) = \beta_l + \theta_l f(t)$, with $f(t)$ a function of time. The null hypothesis for proportionality to be tested is $H_0 : \theta_l = 0$.

We use the Cox model mainly due to its advantage of being a semi-parametric model. At the same time, it handles survival data properly, incorporating information on censoring and survival time, and allowing for the relationship between several risk factors or exposures simultaneously. However, despite having the advantage of no assumptions on the shape of the baseline hazard, the assumption of proportionality may not hold under certain circumstances. A former study that focused on a subset of this military sample composed of only Academy officers showed that pilots had higher risk of death only in the first years of military duty, with subsequent lower risk of death at later ages. Since this previous work had information on deaths by casualties and other causes, it was possible to employ a Fine and Grey competing risks approach, which showed an important higher risk of death by casualties among pilots relative to their counterparts. However, this association was restricted to the beginning of follow-up, and mortality due to other causes throughout the period was even lower among pilots (Lego, Turra, and Cesar 2017). This crossover appears again in this present analysis, that considers not only Academy officers, but also Secondary and Tertiary educational level military personnel. This in turn could violate the principles of proportionality in the model. Hence, motivated by former evidence and the fact that we now lack data on deaths by casualty, we first test if there is evidence of a career effect that changes with time, especifically allowing for different effects at earlier and later duration of follow-up, using the approach suggested by Rodríguez (2017). The results indicate that career significantly interacts with time when we consider military personnel before age 35, when both Secondary and Tertiary careers have a protective effect when compared to Academy officers. However, when we consider the interaction of career after age 35 the protective effect for Tertiary level remains, while the sign of effect for Secondary shifts, as shown in Table 3.4. The bottom part of Table 3.4 shows the results before age 35, while the top part of the table describes the effects after age 35. The point estimates show that Secondary career is associated with a 46% increased risk relative to Academy officers after age 35, while associated to a lower hazard before age 35. For Tertiary officers both periods indicate a protective and significant effect. This goes in line with our previous results (Lego, Turra, and Cesar 2017), suggesting that the lower survival among Academy officers in the first years of follow-up is probably attributable to casualties among pilots. With this in mind, and considering that this work aims at mainly investigating the effects of background variables on the overall mortality of a selective group, we restrict the window of survival analysis to ages 35 and 85. This enables us to deal with the potential confounding effect of a especific occupational risk that is not part of our research question in this study. Additionally, by censoring the analysis to age 85 we avoid erratic patterns at older ages that may bias the results.

We then fit models controlling survival time for career type, occupation, place of birth, birth cohort and age at entrance in the institution, as detailed in the results section. Goodness-of-fit and the proportionality assumption are assessed through Schoenfeld residual analysis and tests.

Table 3.4: Cox Regression results with career as a time-varying covariable before and after 35 years of age

Covariates	Hazard Ratio (HR)	Std. Err.	z	P-value	95%CI	
Effect after age 35						
Age	1.0207	0.0042634	4.9	0.0000	1.01237	1.02908
Academy						
Secondary	1.4642	0.0649495	8.6	0.0000	1.34232	1.59724
Tertiary	0.8367	0.0489948	-3.05	0.0020	0.74594	0.93841
Effect before age 35						
Academy						
Secondary	0.1578	0.0195688	-14.89	0.0000	0.12377	0.20124
Tertiary	0.1492	0.0361617	-7.85	0.0000	0.09275	0.23990

Note: variables in time-varying equation interacted with time before age 35
Source: SIGPES/DIRSA (2015)

3.2.3 Comparing vanguard populations

In the final part of this work we reintroduce the conception of vanguard and place the military into perspective now with other low mortality subgroups. In order to accomplish this we compare the probabilities of death by single ages between 35 and 85 years of age. We compute the probabilities from the incidence rates estimated by the survival analysis previously performed. In order to transform the rates into probabilities we use the method described by Preston, Heuveline, and Guillot (2001):

$$q_{x+1} = 1m_{x+1}/1 + (1 - 0.5m_{x+1}) \quad (3)$$

Where $1m_{x+1}$ represent the death rates estimated by single year ages and the 0.5 in the formula represents the assumption that people are dying approximately halfway over the period. However, since the number of deaths and person-years suffer from fluctuations, especially when dealing with smaller subpopulation groups, age-specific rates can be quite erratic and they need to be graduated, especially when one's aim is to compare with other data, as is our own (Preston et al. 1980). We hence employ smoothing splines to our death rates prior to converting them to probabilities, using the approach described by Gu (2014), where the smoothing parameters are chosen by cross-validation. We then compare the smoothed BAF probabilities of death to the probabilities of death of other possible vanguard groups. First we compare to the Male Aggregate - Combined Healthy Participant, RP-2000 Rates(SOA 2012), which is the life table used by the Brazilian Ministry of Defense in estimating pension benefits for the Armed Forces(DoD 2016). We also compare to the life table BR-EMS 2010 of insured lives in Brazil (De Oliveira et al. 2016) and the Brazilian executive federal civil servant mortality (Beltrão and Sugahara 2017) in order to have comparisons within the Brazilian context. We also compare to the US armed forces life table (2010) used by the US Military Office of Actuary in order to estimate benefits for the Armed Forces in the US, in order to have a comparison with another military subgroup in the world.

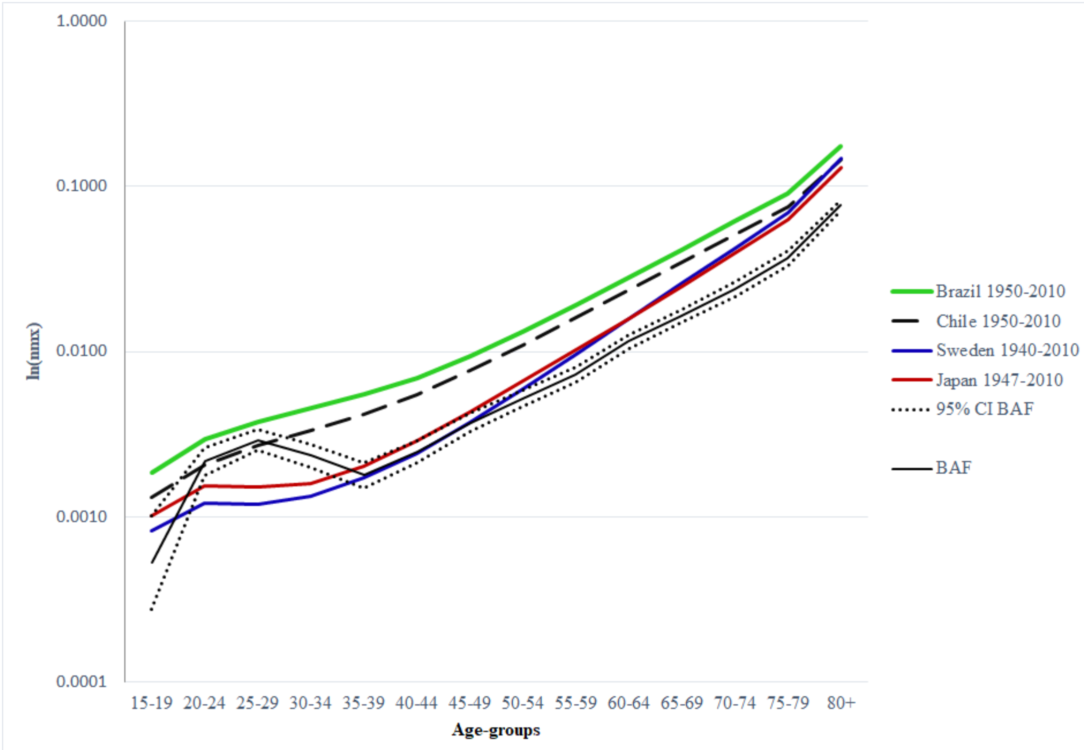
4 Results

4.1 Setting the scene

As our first result, we estimate the average unsmoothed mortality rates for BAF military personnel from 1943-2010 and compare them to the rates from different national populations Figure 4.1. The mortality experience of BAF military after the age of 35 is comparable to the one of adults living in Japan and Sweden. In addition, mortality rates for BAF are significantly lower than for Brazilian and Chilean men over the same period of time. Sweden and Japan started their mortality transitions much earlier than Brazil, and at an initial lower level of overall mortality. For example, male life expectancy at birth was higher than 75 since 1986 in Japan and since 1992 in Sweden (HMD), although it will reach that level only after 2030 in Brazil (UN 2017). Therefore, the advantage of BAF above age 35 over their national counterparts is not unimportant at all, confirming earlier analysis based on a much smaller data sample (Lego, Turra, and Cesar 2017). On the other hand, the estimates of Figure 7.1. are also in line with previous evidence that shown a higher risk of death among pilots at ages below 35 in Brazil and in other countries (Lego, Turra, and Cesar 2017; Inskip, Snee, and Styles 1997). For a complete view of mortality rates by 5-year age groups for all countries used as inputs for Figure 4.1, please refer to Table 7.2 and Table 7.1 in Appendix I.

This result evidences that we can consider BAF personnel a vanguard population subgroup in Brazil, especially when considering ages above 35. Given that fact, we now turn to understand the differences within the group and test whether background factors, such as educational attainment previous to enrollment in the institution and place of birth have any important effect. We also test the effects of career type, occupation and birth cohort.

Figure 4.1: Age-specific mortality rates, by selected countries and BAF, 1940-2010



Source: SIGPES/DIRSA (2015)

4.2 Non-parametric survival analysis

Table 4.1 shows the overall survival descriptive characterics of this subgroup, with percentiles of survival time. The first aspect that stands out is that the median survival for Tertiary career is the highest, with 50% of all individuals surviving up to age 84.80 by the end of follow-up. Academy officers subsequently follow with age 83.83, and lastly the Secondary with 80.29. This is a non-parametric summary statistics, but it already provides some indication of the effects. Analyzing the first percentile quarter is also important. We can see that 25% of persons born to cohorts between years 1930-1960 live until 73.42 years of age while that age for the previous 30 years (1900-1930) was 67.35, suggesting mortality improvement between birth cohorts. Tertiary higher rank also has the highest age at which 25% of persons are alive, when compared to the other occupations.

Table 4.1: Percentiles of survival time according to variables and summary statistics

Variables		No. of subjects	Survivors	Deaths	Survival Time (in ages)	
					25%	50%
Career						
	Academy	4,672	3,771	901	74.98	83.83
	Tertiary	2,641	2,104	537	75.38	84.80
	Secondary	6,028	4,382	1,646	68.53	80.29
Region						
	Northern	4,682	3,140	1,542	70.46	81.71
	Southern	8,659	7,117	1,542	73.13	83.45
Birth Cohort						
	1900-1930	1,822	661	1,161	67.35	80.27
	1930-1960	8,910	7,096	1,814	73.42	83.45
	1960-1980	2,609	2,500	109	.	.
Age at entrance						
	15-20	8,044	6,581	1,463	73.81	83.44
	20-25	3,371	2,381	990	70.22	81.61
	25-30	1,397	961	436	70.74	81.88
	30-35	409	273	136	71.75	81.31
	35-40	95	51	44	66.10	77.39

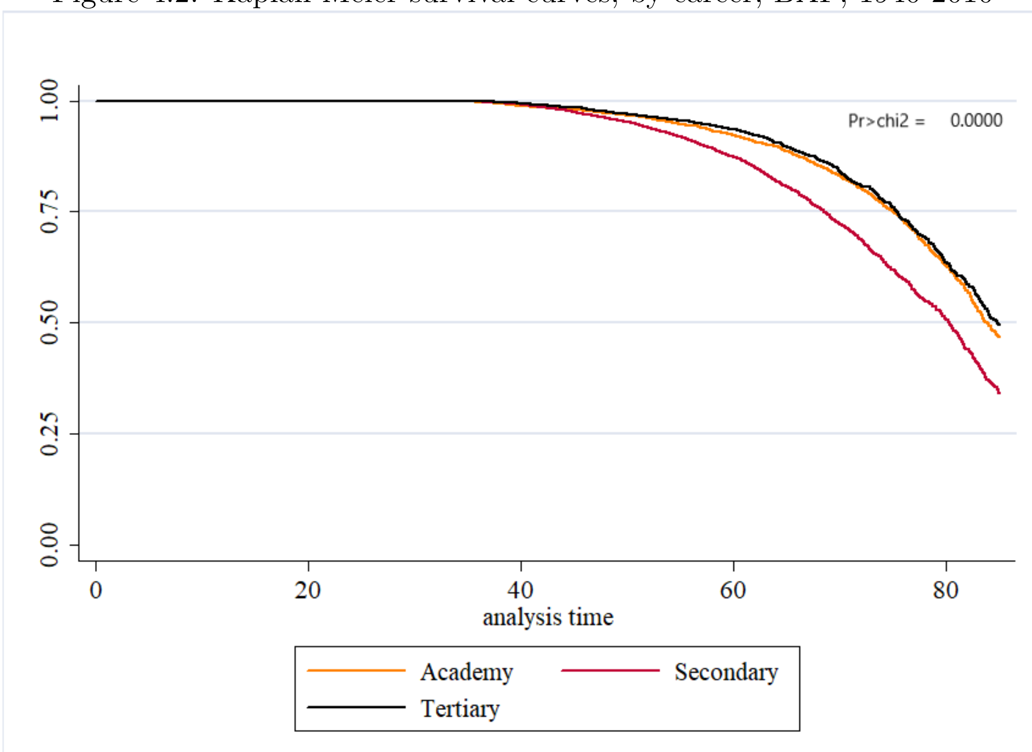
Table 4.1 continued from previous page

Variables		No. of subjects	Survivors	Deaths	Survival Time (in ages)	
					25%	50%
	40-45	25	10	15	66.46	80.56
Occupation, by career type						
Academy						
	Pilots	3,172	2,540	632	74.92	84.04
	Infantry	478	375	103	75.85	82.34
	Intendant	1022	856	166	73.79	82.69
Tertiary			0			
	Higher rank	1,360	1,090	270	76.20	.
	Lower rank	1,281	1,014	267	73.94	83.90
Secondary						
	Service	6,028	4,382	1,646	68.53	80.29

Source: SIGPES/DIRSA (2015)

In line with our descriptive table, we have the Kaplan-Meier survivor curves, where the trajectories by the existing variables are graphically explored. Figure 4.2 shows the curves by career, which are estatistically different according to the log-rank and Peto test. As a reminder, the log-rank tests compare the number of observed to expected events, while the peto test is similar to the log-rank, but it puts different weights along the survival curve. It especifically puts more weight at the begining of the survival curve, accounting for observations that have shorter follow-up time (Klein and Moeschberger 1997). We employ both methods because we have short (less than a year) and long (maximum 72 years) follow-up survival times. Hence, in order to be more cautious about the weight given to survival follow-up, we test the survival curves using those two criteria.

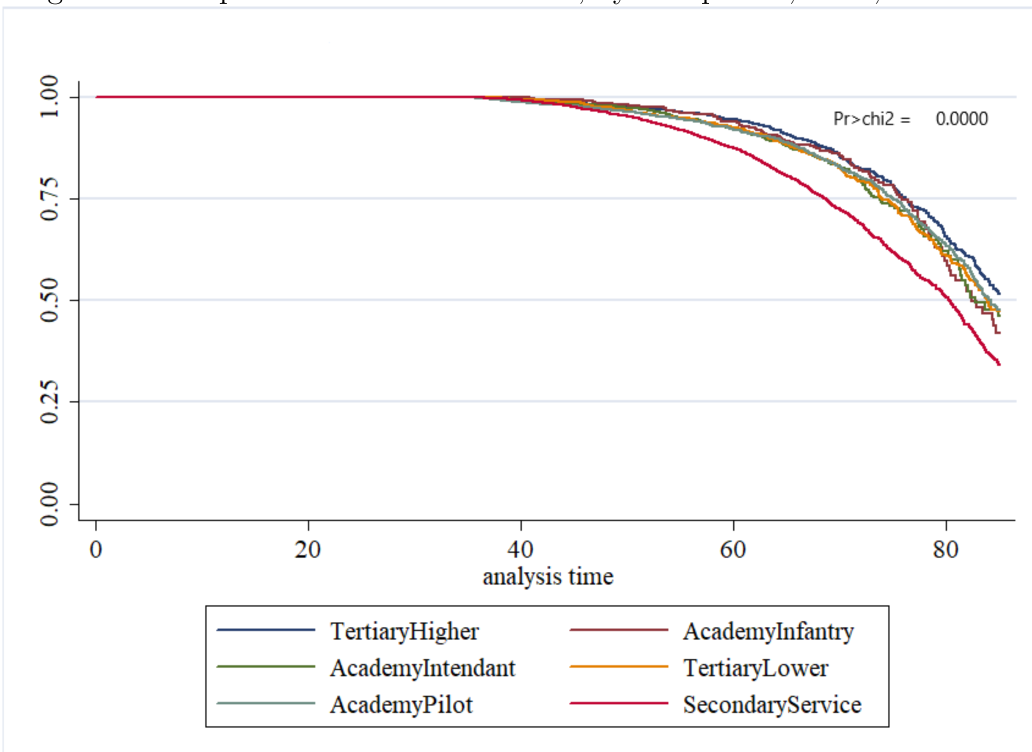
Figure 4.2: Kaplan-Meier survival curves, by career, BAF, 1940-2010



Source: SIGPES/DIRSA (2015)

We can see from Figure 4.2 that the survival curve of the Secondary military personnel is always below that of Academy officers and Tertiary personnel. The survival curves of Academy versus Tertiary is very similar graphically, but the tests indicate that they are barely statistically significant, and so suggest that they are different. Tertiary level then presents the higher survival curve. In Figure 4.3 we can see the same plot but now considering all occupations. Again, occupation service, the represents career Secondary, is below all other occupations, while higher Tertiary, that is composed of doctors and engineers, is the one curve in the top of all the survival curves.

Figure 4.3: Kaplan-Meier survival curves, by occupation, BAF, 1940-2010

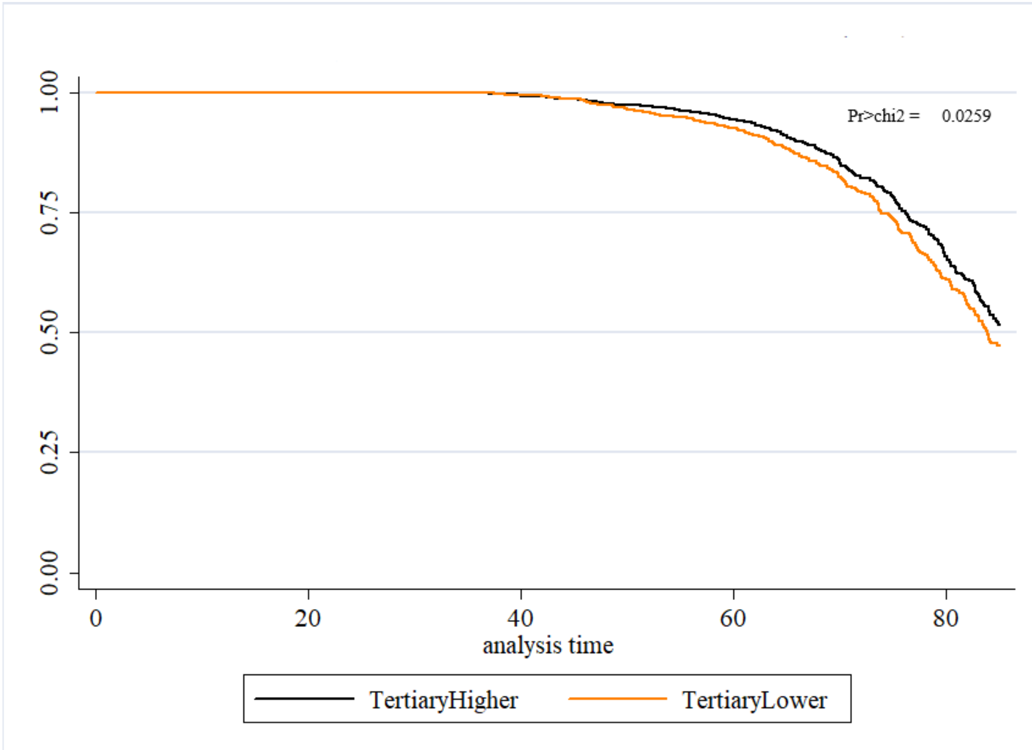


Source: SIGPES/DIRSA (2015)

Interestingly, as Figure 4.4 shows, coming from a Tertiary level of education previous to enrolling the military institution is not enough, since the type of university degree a person has is also important. Here we can see that the survival curve for doctors and engineers, who make up the Higher Tertiary, is above the Lower Tertiary. This is interesting to discuss how different types of tertiary level courses actually select different background persons. However, the difference between the two curves is barely statistically significant.

Interestingly, when we analyze the survival curves by region of birth, we can also see that those individuals who were born in the more developed regions in Brazil (Southern) experience a survival advantage relative to their national counterparts who were born in the less developed regions (Northern). The log-rank tests are highly significant. This

Figure 4.4: Kaplan-Meier survival curves, by Tertiary level, BAF, 1940-2010



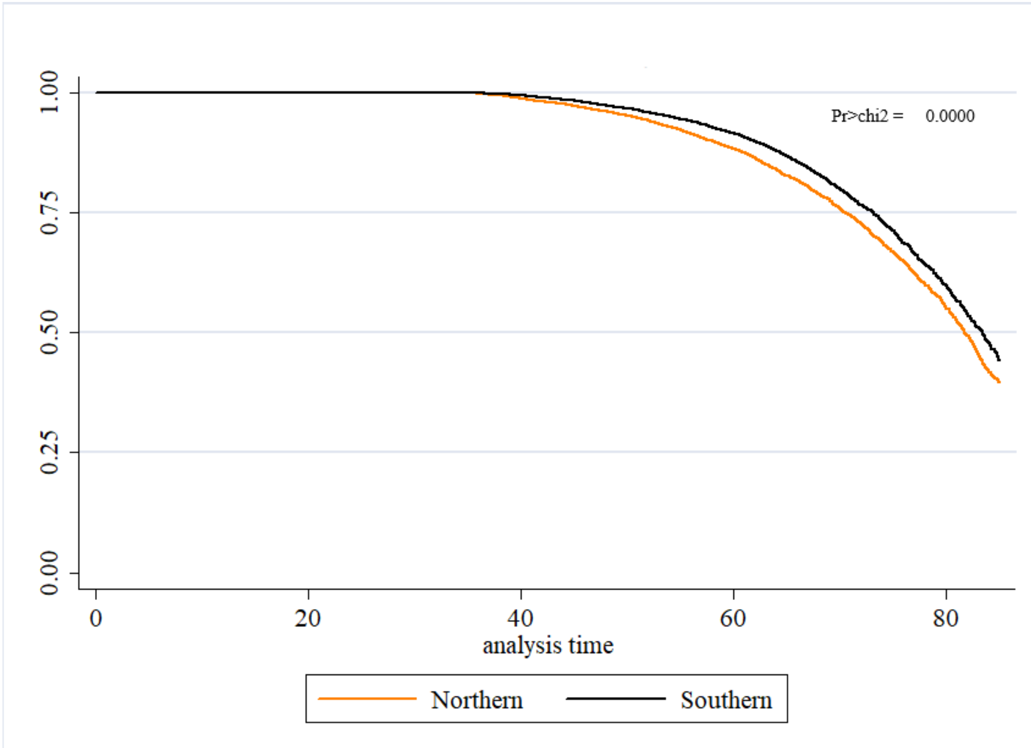
Source: SIGPES/DIRSA (2015)

result suggests that being born in less developed regions may still matter throughout a person's lifecourse, even when considering a selective institution such as the military.

Another interesting result is looking into mortality between birth cohorts. The last birth cohort is very recent (people born between 1960-1980), and so is shortly followed. However, when we analyze the older cohorts born between 1900-1930 and between 1930-1960 we see an indicatation of improvement in survival between the periods. The curves are statistically significant.

Following the graphical analysis and after testing for the significance of the available variables throughout log-rank and peto tests, we now turn to the Cox regression models in order to estimate the effects and test if those differences found in the non-parametric analysis still hold when we perform multivariate analysis and control for all the risks simultaneously.

Figure 4.5: Kaplan-Meier survival curves, by region of birth, BAF, 1940-2010

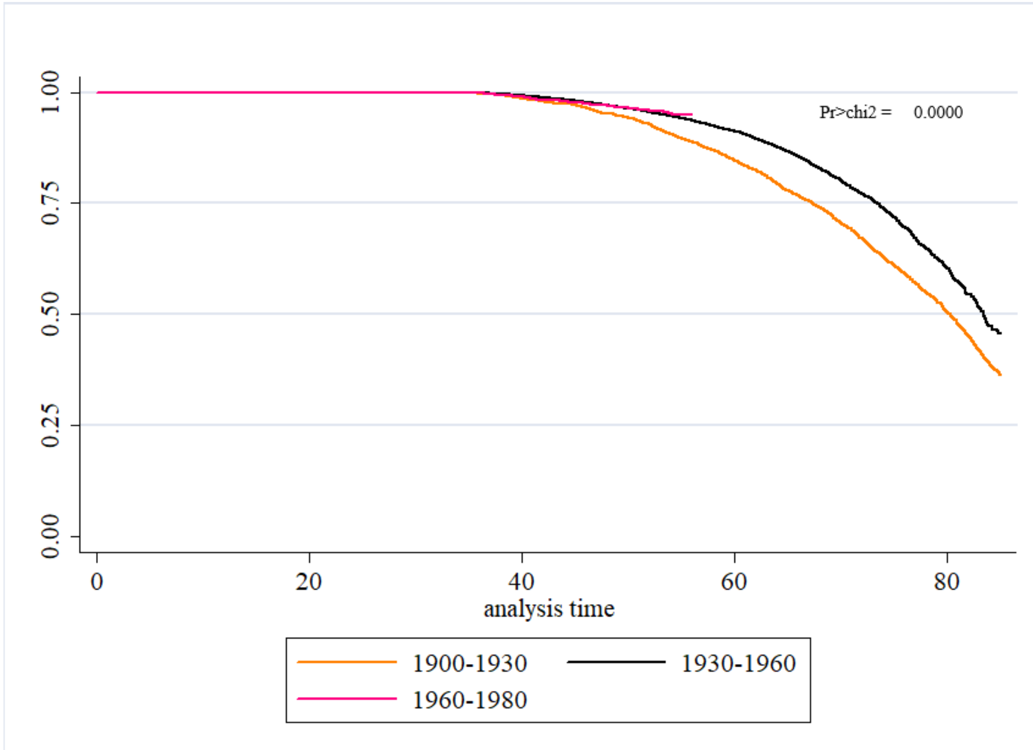


Source: SIGPES/DIRSA (2015)

4.3 Cox regressions

We first estimate models gradually adding one covariate at a time and checking for proportionality departures. We always control for age at entrance, since our survival analysis allows for different time entries. We use age at entrance as a continuous variable on all models and to control for age differential at entrance. Age is also our time scale. The sequence we adopted for developing the model was very straightforward and followed from the simplest to the saturated model, according to our variables of interest. If a given covariate proved statistically significant in the model, it was retained in the model (Models I-IV). In addition, we developed a further model that includes occupation but excludes career, since one is contained in the other (and so keeping both leads to collinearity issues), but we wanted to test the effect of specific occupations on the risk of death (Model V). We use this strategy to first explore the simultaneous effect of covariates on the risk of death, to provide us with a more precise idea of what is important to determine the survival experience of this population subgroup.

Figure 4.6: Kaplan-Meier survival curves, by cohort of birth, BAF, 1940-2010



Source: SIGPES/DIRSA (2015)

1. I: $h(t) = h_0(t)\exp(\beta_1 Age)$,
2. II: $h(t) = h_0(t)\exp(\beta_1 Age + \beta_2 Career)$,
3. III: $h(t) = h_0(t)\exp(\beta_1 Age + \beta_2 Career + \beta_3 Region)$,
4. IV: $h(t) = h_0(t)\exp(\beta_1 Age + \beta_2 Career + \beta_3 Region + \beta_4 Cohort)$,
5. V: $h(t) = h_0(t)\exp(\beta_1 Age + \beta_3 Region + \beta_5 Occupation)$.

Table 4.2 presents results for Models I, II, III, IV and V. We can see that all covariates are significant by the Wald statistic and the CareerTertiary has a protective effect relative to the reference, that is Career Academy. On the contrary, Secondary is associated to an increased hazard relative to Academy officers, even when we include Region of birth in the model (Model III). Interestingly, when we introduce the birth cohort in the model, region of birth loses significance and the hazard ratio, as shown in Figure 4.9, becomes pratically 1. In addition, the significance of the Tertiary protective effect relative to Academy officers becomes less strong, despite still significant. The last model we show here is the one that includes the specific occupations, instead of the grouped Career variable. For all models here considered, Academy officers are the referece for career type, TertiaryHigher are the reference of occupation, Northern is the reference of region and 1900 Cohort is the reference for cohort.

Table 4.2: Regression Results for Cox models I to V

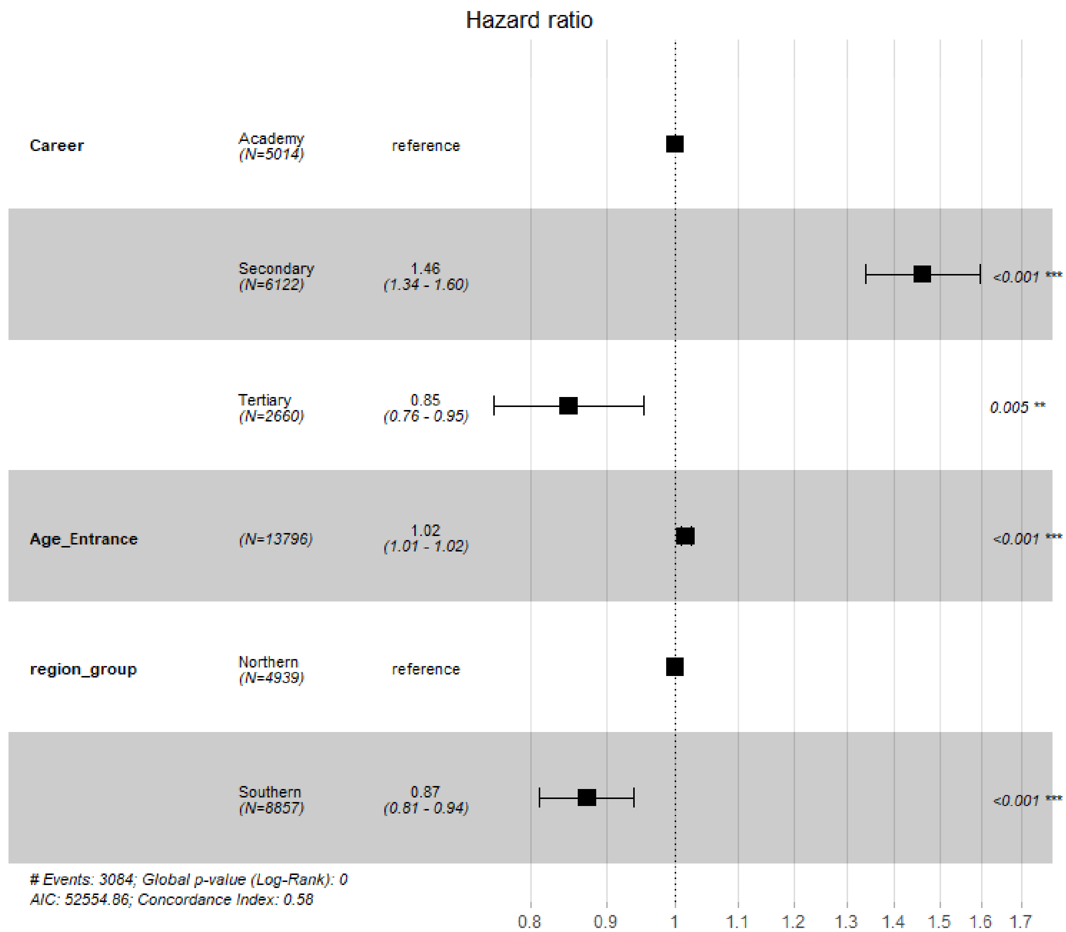
	Dependent variable:				
	Age				
	(Model I)	(Model II)	(Model III)	(Model IV)	(Model V)
CareerSecondary		0.395^{***} (0.044)	0.379^{***} (0.045)		0.412^{***} (0.045)
CareerTertiary		-0.160^{***} (0.059)	-0.164^{***} (0.059)		-0.133^{**} (0.058)
Age	0.021^{***} (0.004)	0.017^{***} (0.004)	0.016^{***} (0.004)	0.018^{***} (0.004)	0.007 (0.004)
Region:Southern			-0.136^{***} (0.037)	-0.138^{***} (0.037)	-0.073^{*} (0.038)
AcademyInfantry				0.235^{**} (0.118)	
AcademyIntendant				0.307^{***} (0.102)	
TertiaryLower				0.261^{***} (0.088)	
AcademyPilot				0.306^{***} (0.079)	
SecondaryService				0.668^{***} (0.067)	
Cohort1930-1960					-0.324^{***} (0.044)
Cohort1960-1980					-0.477^{***} (0.111)
Wald Test	30.400^{***} (df = 1)	196.140^{***} (df = 3)	209.880^{***} (df = 4)	218.190^{***} (df = 7)	269.290^{***} (df = 6)
LR Test	29.124^{***} (df = 1)	196.295^{***} (df = 3)	209.763^{***} (df = 4)	219.008^{***} (df = 7)	266.786^{***} (df = 6)
Score (Logrank) Test	30.434^{***} (df = 1)	199.641^{***} (df = 3)	213.480^{***} (df = 4)	222.134^{***} (df = 7)	273.443^{***} (df = 6)

$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Source: SIGPES/DIRSA (2015)

Another way to visualize the results of Model III is in Figure 4.7. Here we can see the reported hazard ratios, with their corresponding confidence intervals and associated sample sizes for each covariate. The right side of the plot indicates hazard ratios above 1, and represents an increased risk of death relative to the reference category. The left side of the plot indicates hazard ratios below 1, and so represents a protective effect of a given covariable relative to its reference. We see more clearly that Secondary career is associated with an increase of 46% in the risk of death, relative to the Academy career, while the Tertiary career has a significant protective effect when compared to Academy officers, albeit a wider confidence interval than the Secondary career.

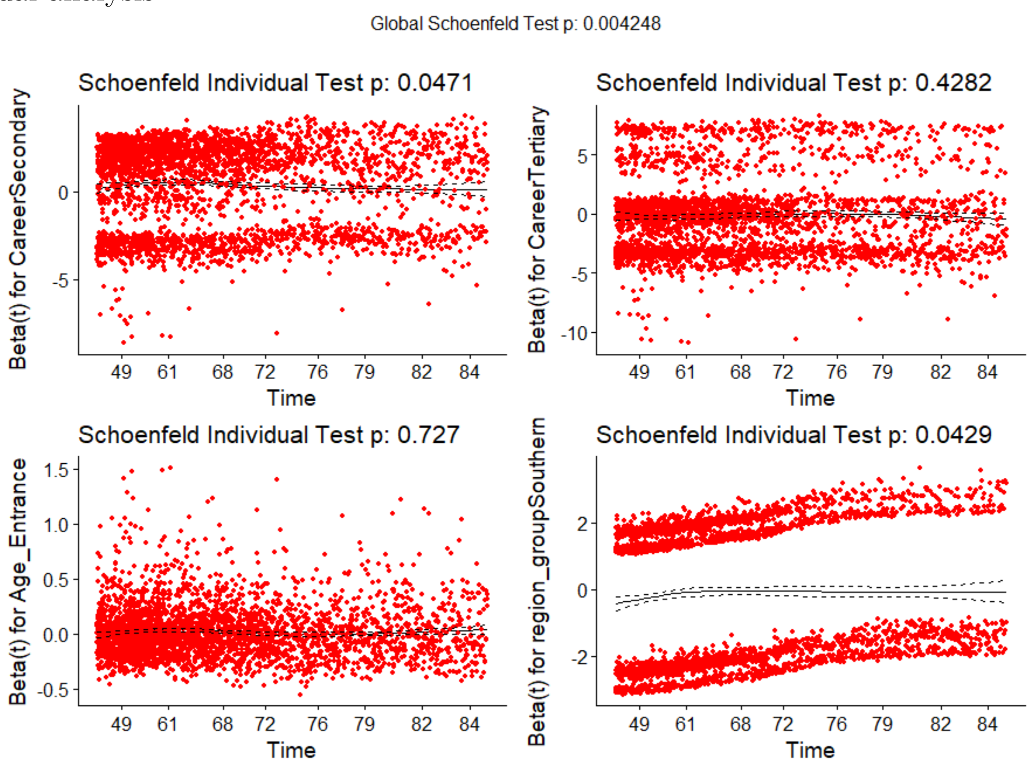
Figure 4.7: Forest plot of Model III, with reported Hazard ratios, confidence intervals and summary statistics



Source: SIGPES/DIRSA (2015)

In addition, those who were born in the Southern regions of Brazil also experience a protective effect relative to those who were born in the Northern, less developed regions in the country. The scaled Schoenfeld p-value test together with the analysis of residuals is presented in Figure 4.8. We can see that the global test for non-proportionality is significant, showing the that Model violates the assumption. The test statistics for each covariate individually indicates departure from the proportionality assumption. Career Secondary and region Southern are the covariates on the limit for the test. Figure 4.8 shows a slight inclination of region upwards, but already at older ages.

Figure 4.8: Schoenfeld test for proportionality, Model III, with reported p-values and residual analysis



Source: SIGPES/DIRSA (2015)

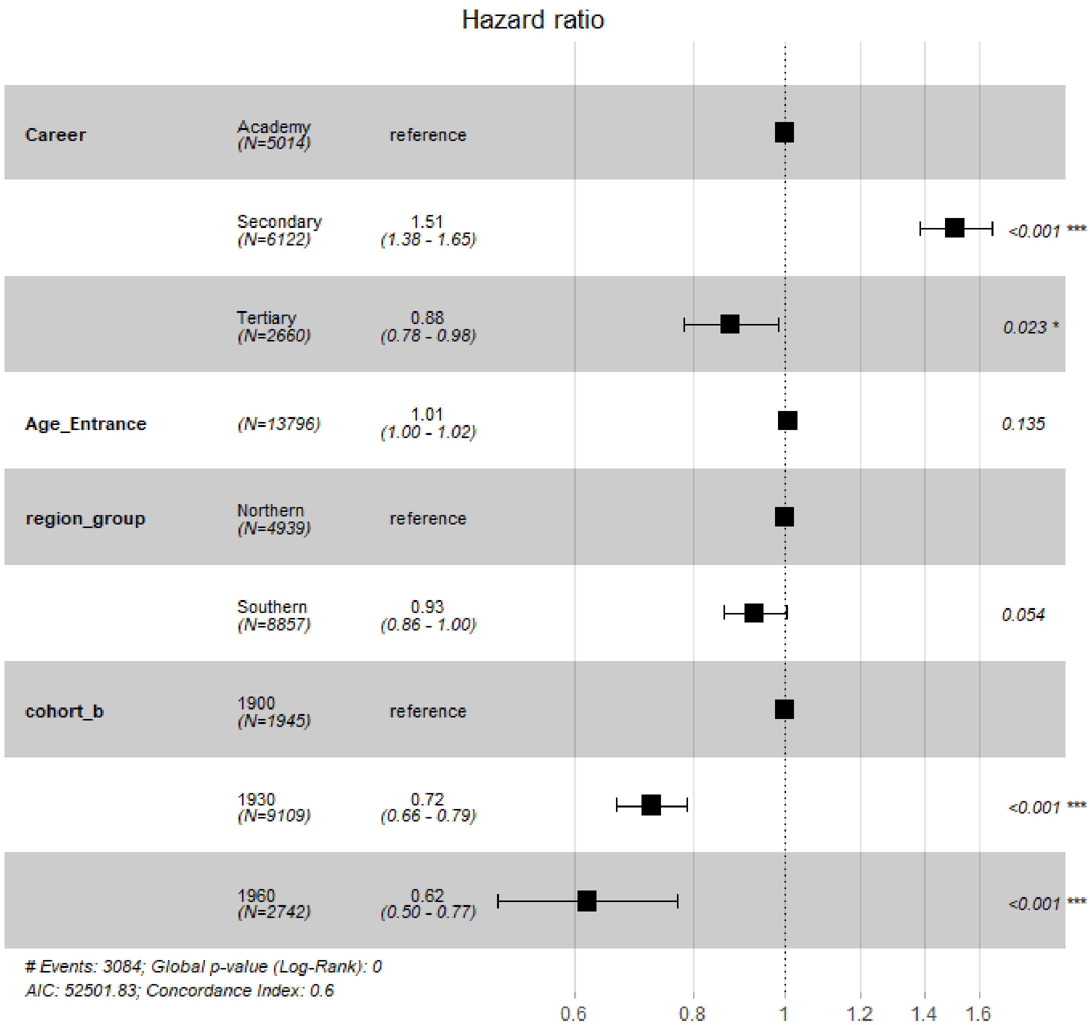
Nonetheless, the proportionality tests indicate strong departure of this model from proportionality, due to the new covariate. The results makes sense, since despite birth cohort being fixed in time, its effect vary as people age and probably become more important with time.

Again, a summary plot with the hazard ratios are provided in Figure 4.11. To the left we have the protective effects, which now include only the Southern region. In this model, the reference is not Academy career anymore and now it is the Higher

Tertiary. Higher Tertiary are doctors and engineers, and this model corroborates that their risk is lower compared to all other occupations. Interestingly, the occupation Service, which is also the Secondary Career, has an increased risk of death that is double the amount when compared to Higher Tertiary. This means that coming from a lower educational background is possibly associated to lower survival when compared to higher educational background.

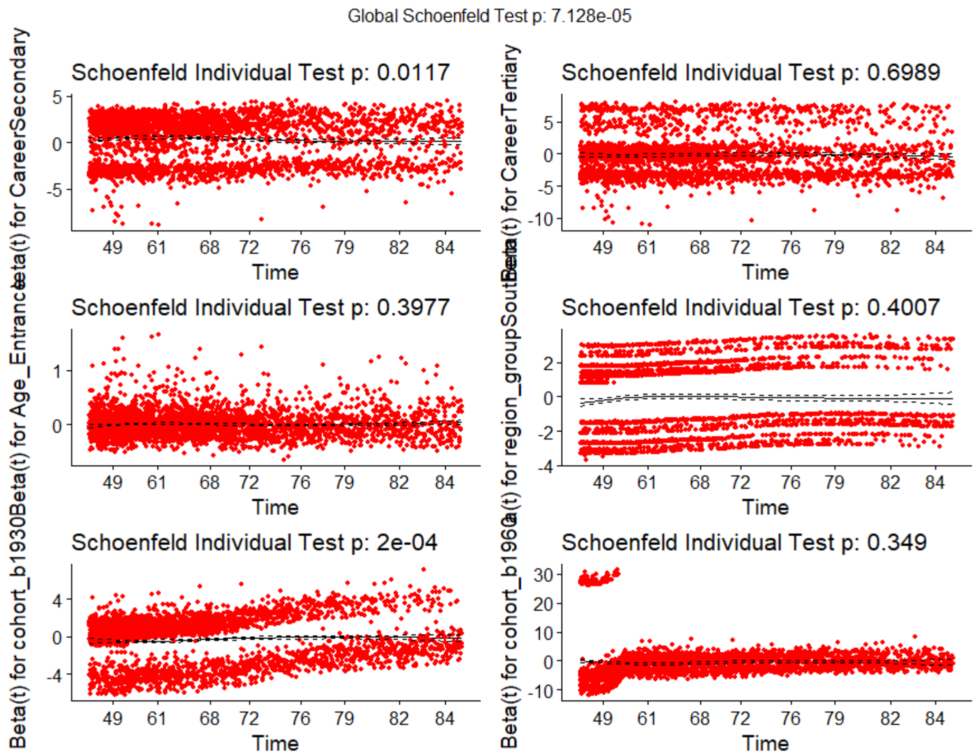
Nonetheless, it is important to account for the fact that Figure 4.12 shows Service occupation departing from the proportionality assumption. Pilots are also in the test limit.

Figure 4.9: Forest plot of Model IV, with reported Hazard ratios, confidence intervals and summary statistics



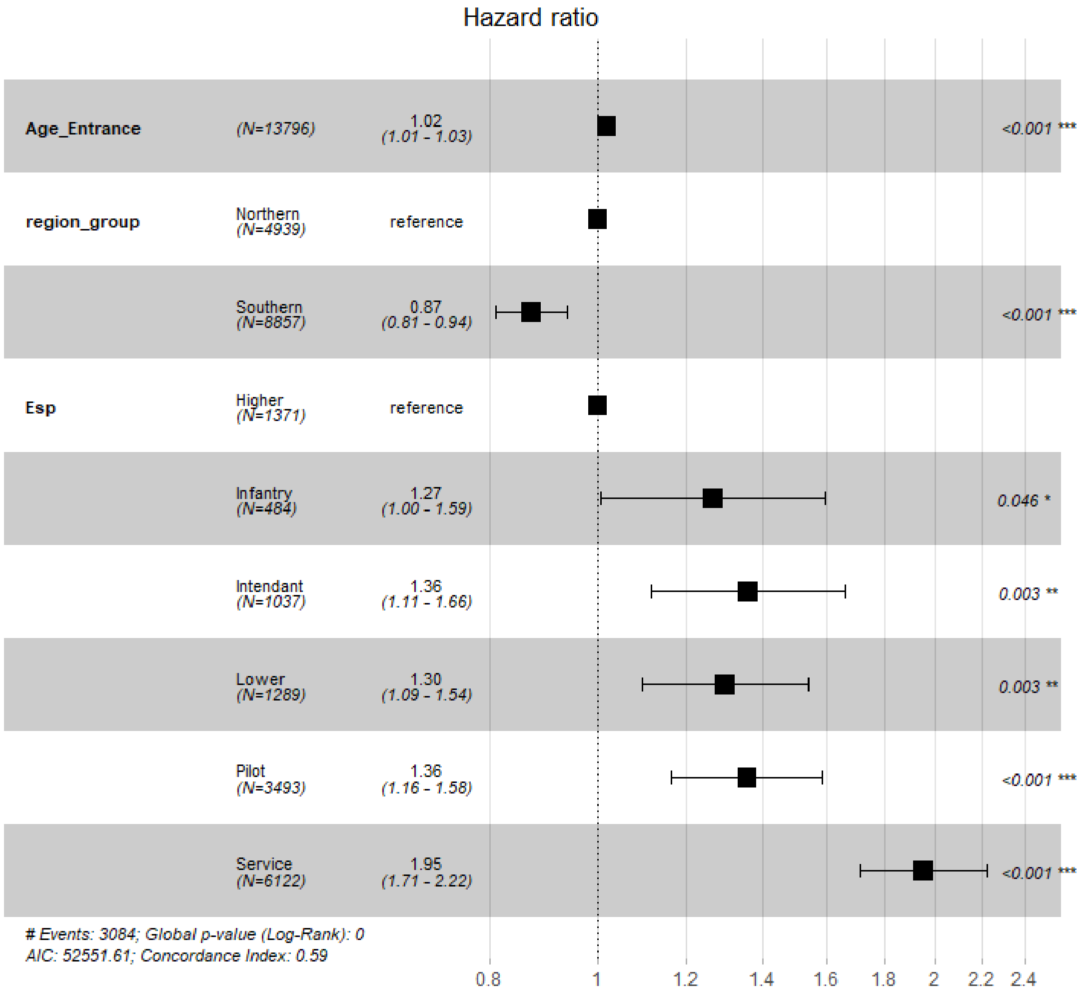
Source: SIGPES/DIRSA (2015)

Figure 4.10: Schoenfeld test for proportionality, Model IV, with reported p-values and residual analysis



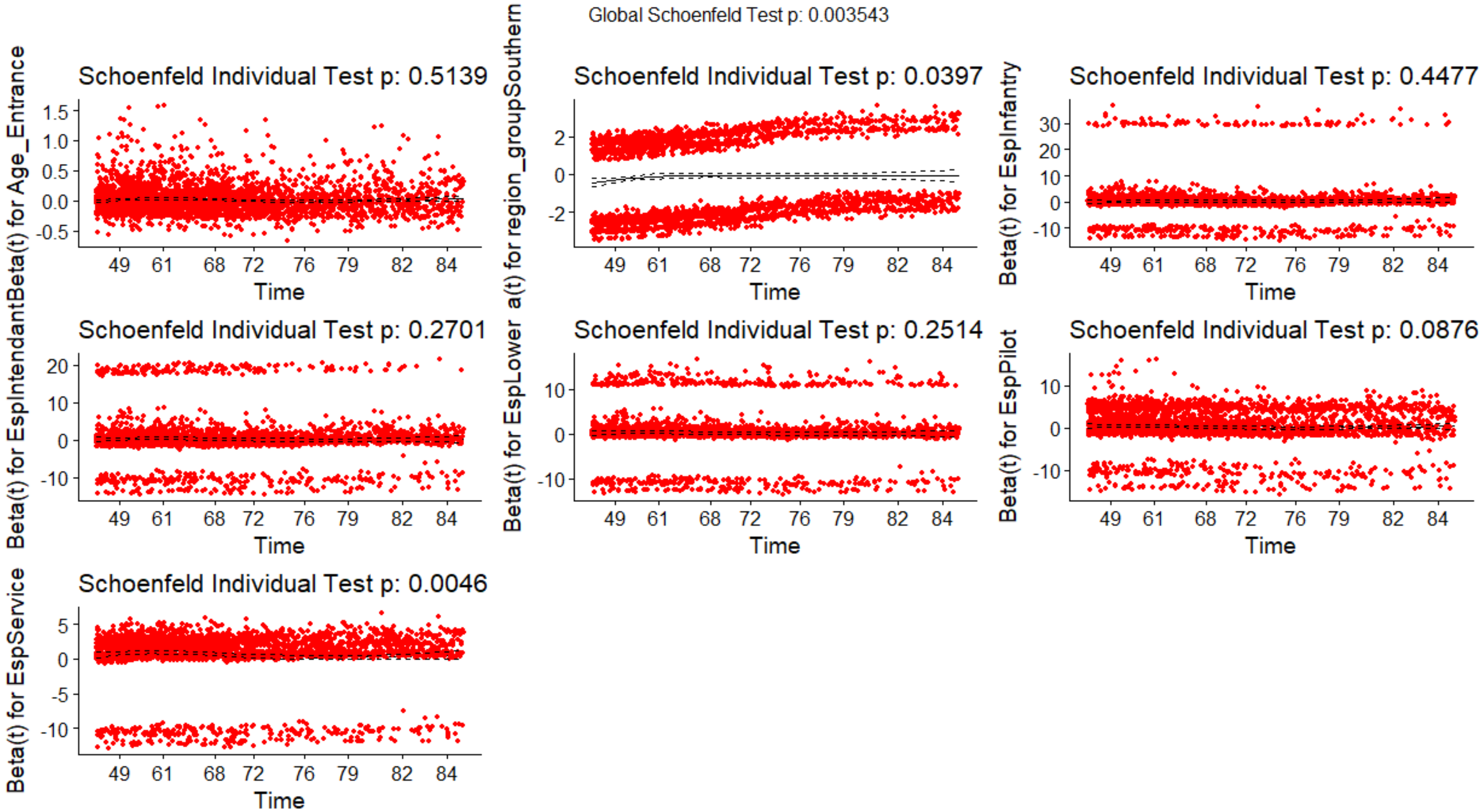
Source: SIGPES/DIRSA (2015)

Figure 4.11: Forest plot of Model V, with reported Hazard ratios, confidence intervals and summary statistics



Source: SIGPES/DIRSA (2015)

Figure 4.12: Schoenfeld test for proportionality, Model V, with reported p-values and residual analysis



Source: SIGPES/DIRSA (2015)

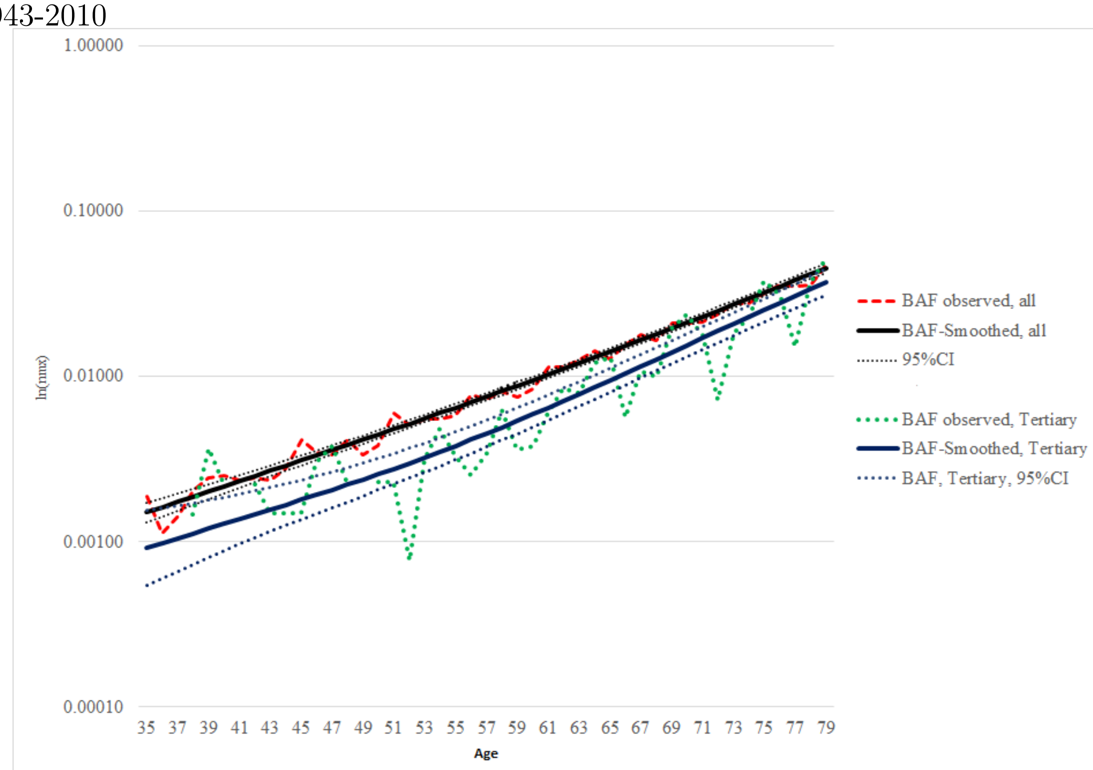
We can conclude from the sequence of models that region and Career are important predictors to understand mortality differentials within this group. Birth cohort is a more problematic covariate to evaluate in a proportional hazard model due to its probable time varying effect. Interestingly, even within a selective population subgroup, mortality differences persist and these differentials seem to be associated to educational background and place of birth. Hence, the military institution or any other setting that aims at standardizing individuals may not be strong enough to offset the effects of having attained only until secondary school or been born in the less developed regions in Brazil. Lastly, important to note that most of our models suffer from departures of an important assumption of the Cox model: proportional hazards. However, we choose to maintain the models to first explore our database despite this departure. There is an important debate on the validity of Cox models once they depart from the proportionality assumption. On the one hand, some authors argue that this departure is very important and that the coefficients lose interpretation (Hosmer, Lemeshow, and May 2008). On the other hand, however, other authors state that it depends on the purpose of research. Even in a context of proportionality violation, the parameter estimate represents average strength of the covariate impact on the hazard rate. If it suffices to estimate the average impact, one can keep the model (Allison 2010). Hence, we can think of our estimates as an average impact of covariates on the hazard rate. For now, it suffices to know this average impact to pave the way towards further investigation procedures.

4.4 Vanguards of longevity: how great is BAF's survival advantage?

When we compare BAF mortality experience with other low mortality countries in the same period, as well as their average national counterparts as shown in Figure 4.1, their survival advantage is very evident. However, a more thorough analysis of survival within military careers revealed some important differences, especially when accounting for educational background. Models II, IV and V showed how Tertiary career is positively associated to survival. Hence, we estimate mortality rates for this group separately, smooth them and transform them into probabilities of death by single-age groups. Afterwards, we compare with other subgroups in Brazil that are also potentially vanguard, such as the insured lives and civil servants.

Figure 4.13 first presents the mortality rates estimated directly from the survival incidence, which we are calling "observed". Then, we smooth the mortality rates throught smoothing splines. For evaluating the rates, please refer to Table 8.1 in the Appendix.

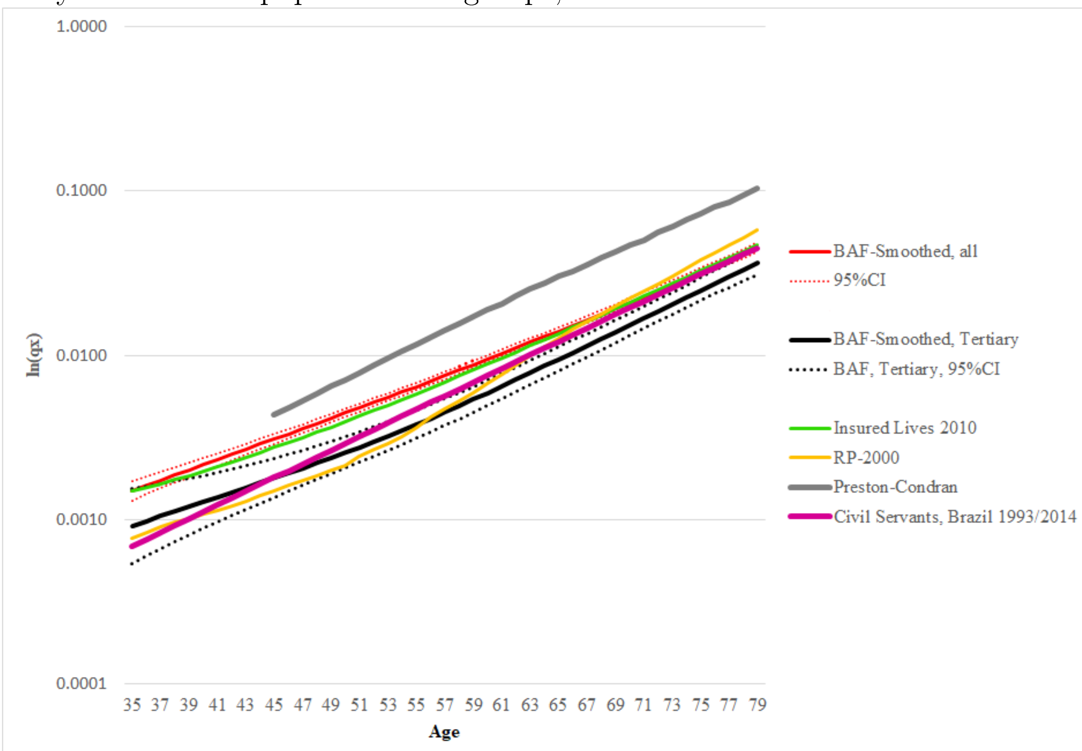
Figure 4.13: Mortality rates, observed and smoothed, BAF all and BAF Higher Tertiary, 1943-2010



Source: SIGPES/DIRSA (2015)

We can see from this figure that the pattern for Tertiary level is quite noisy, since there are few cases and fluctations are even more important when considering only one-year age intervals. However, there is a trend and the observed values fit in well the confidence intervals. These are the log rates. In Figure 4.14 we present the rates transformed into probabilities and compare with other subgroups. It is very evident the extent of BAF's advantage, especially if we consider the Tertiary level. Here we present the Tertiary Higher, which was shown to be probably the subgroup with the highest survival among BAF personnel. we can see that their q_{x+1} function is very close to civil servants in Brazil and also to the RP-2000 life table, since their estimates usually fall wihtin BAF's confidence intervals. The latter actually confirms the suitability of this life table for BAF personnel, since it is used by the Ministry of Defense office of actuary in Brazil to estimate pension benefits.

Figure 4.14: Probabilities of death by single ages, smoothed, BAF all,BAF Higher Tertiary and selected population subgroups, 1943-2010



Source: SIGPES/DIRSA (2015)

Certainly, we could infinitely search for other subgroups that we deem vanguards of longevity and continue with this analysis indefinitely. The point here is to first place military personnel into context and search for our own vanguard population in the developing world, and try to understand if this approach helps us to improve our knowledge of the pathways that the many subgroups in a given population undergo throughout the demographic transition, and how does each subgroup translate these gains.

5 Conclusion

5.1 Towards a subgroup mortality perspective

In this work, we employed a strategy that has been used by some researchers in mortality studies as an attempt to understand what is the advantage of a vanguard group in a developing country and if background aspects such as education and place of birth have an important effect on survival (Andreev et al. 2011; Winkler-Dworak and Kaden 2014; Lemez and Baker 2015; Enstrom and Breslow 2008a; McCullough et al. 2000; Luy, Flandorfer, and Di Giulio 2015; Luy 2003; Costa 2012; Costa 2003; Costa and Kahn 2010). This type of exercise can be insightful, since we are dealing with a very selective subgroup that could possibly have less confounding elements coming into play, different from the very heterogenous feature of populations. Our results point out four interesting aspects: 1. corroborate previous estimates that showed how selective the military are relative to their average male national counterpart, and also to neighboring countries, being comparable to low mortality societies such as Sweden and Japan (between years 1940-2010)(Lego, Turra, and Cesar 2017; Besco et al. 1995). 2. Indicate a new facet of their survival advantage by comparing their probabilities of death to other vanguard groups in Brazil such as the insured lives (De Oliveira et al. 2016) and executive civil servants (Beltrão and Sugahara 2017). 3. Provides an estimate for tertiary level educational mortality in Brazil, as well as it shows that education and place of birth, here defined as part of a person´s background, are still important to explain mortality diferentials, even in a selective setting. Lastly,and related to the last aspect, background seems to matter more for survival advantage (i.e., higher educational levels, which in turn is a proxy for life conditions) than the military training and tough screening/selecting at the recruitment process. If that was not the case, we should expect that Academy officers, who enter at very early ages and through a very demanding health and coognitive selection process, that this group would be the one with higher survival, even accounting for the higher risk of death in the first years. Hence, the institution may not be stronger than a person´s background, going in line with "scarring effect" argument (Preston, Hill, and Drevenstedt 1998a). However, in order to appropriately adjust for all those factors we would need more information at the individual levels. Despite being a long follow-up longitiduinal database, it has still limitation information, so the extent to which models are able to explain associations is more uncertain. In addition, this latter restult relates in a sense to the literature on inequality. The broader literature on mortality differentials shows that despite continuous increases in life expectancy, lifespan inequality still varies greatly within and between countries, and that widening inequalities in mortality have been reported for many developed, Western European countries, and such process started before the welfare reforms of the 1990s, stressing the importance of the subject (Mackenbach 2003, Mackenbach (2012); Gillespie, Trotter, and Tuljapurkar 2014). An earlier research by Feldman et al. (1989) used the National Health and Nutrition Survey Epidemiologic follow-up study to examine mortality by educational levels among white males and females, while Preston and Elo (1995a) used the National Longitudinal Mortality Study to investigate the same issue. Both studies conclude that both additive and proportional mortality differentials appear to have widened among white persons. More recent work on the topic continues to support that evidence and highlight the importance of socioeconomic background on mortality gains (Mark D. Hayward, Hummer, and Sasson 2015; Lleras-Muney 2005; Nepomuceno and Turra 2016). Some authors, on the other hand, argue that the recent variability of the relationship between life expectancy and inequality results from the very different responses of life expectancy and life span inequality to age-specific mortality change (Gillespie, Trotter, and Tuljapurkar 2014), and thus focus on a more purely demographic argument. With this dataset, we are able to assess if different career types (proxy for wages, career success, risk-seeking/risk-averse personality traits and educational background), place of birth (proxy for childhood conditions and broader contextual background) are relevant for explaining mortality differentials among the military who enrolled the institution between years 1943-2000. Analyzing these differentials within a selective population subgroup can be valuable for a deeper compreehension on the widening mortality differentials that populations are facing around the world. Different segments of society benefit from mortality progress: mortality gains are not only unequal among different segments of society, but there seems to be a persistent inequality in those gains through time. In addition, this persistent inequality appears to be not exclusive to developing countries, but also to more egalitarian societies that not only rely upon a strong welfare state system, but also whose demographic transition has happened slowly and has already ended, such as the Swedish case. This means that cohorts from past higher mortality and also possibly past higher inequality have already exit the population and that younger cohorts should be benefiting from mortality progress more intensively towards the most advantageous segments of the population than in fact they are. This poses important future research agenda for the mechanisms underlying persistent mortality inequality and why different segments of society, even in an egalitarian context, are not showing signs of convergence in terms of mortality progress towards vanguard groups.

Important to note that among the concept of vanguards of longevity we have not included centenarians and super-centenarians, the ultimate examples of longevity. This is because when we are dealing with the distinction between vanguard and non-vanguard longevity we are comparing a specific subgroup with their national counterparts of the *same age*, as a means of evaluating if the mortality trajectories within a given population differ substantially from those who benefit first or more intensively from mortality progress. In other words, this is related to how the demographic transition unfolds within each context and how it reaches different segments of society in terms of survival gains. Centenarians and super-centenarians, on the other hand, are the *ultimate* and cummulated survival experience. All this evidence is intimately connected to our first research question, and we employ the concepts of vanguard subgroup and survival advantage to analyze whether trajectories between vanguard and non-vanguard population subgroups in Brazil can provide us with further understanding of the pathways to lower mortality. We hope with this exercice to show the importance of anlaysing this type of group.

As a future agenda we seek to incorporate health measures in our database to test if this survival advantage among BAF military is also translated into improved health. We argue that focusing in certain subgroups of the population that are more homogenous and selective may help us further understand the mechanisms associated to lower mortality.

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7 Appendix I

Table 7.1: Mortality rates estimated with poisson, by summing all deaths and person-years throughout the period 1940-2010, chile, Sweden, Japan and BAF

Age	BAF 1943-2010			Sweden 1940-2010		
	Deaths	Exposure	Rate	Deaths	Exposure	Rate
15-19	9	20098	0.0004	15854	19158080	0.0008
20-24	110	61351	0.0018	23474	19418654	0.0012
25-29	182	73294	0.0025	23695	19910817	0.0012
30-34	156	76883	0.0020	26833	20102118	0.0013
35-39	118	77243	0.0015	33994	19872460	0.0017
40-44	169	76666	0.0022	46637	19312458	0.0024
45-49	252	74663	0.0034	68985	18443658	0.0037
50-54	315	66475	0.0047	104097	17464975	0.0060
55-59	359	53536	0.0067	155849	16213752	0.0096
60-64	462	41242	0.0112	227787	14496037	0.0157
65-69	485	29942	0.0162	317709	12273131	0.0259
70-74	405	17743	0.0228	414888	9821798	0.0422
75-79	366	10170	0.0360	491781	7096214	0.0693
80+	661	8652	0.0764	989004	6674619	0.1482

Table 7.2: Mortality rates estimated with poisson, by summing all deaths an person-years throughout the period 1940-2010, chile, Sweden, Japan and BAF

Age	Japan 1947-2010			Brazil 1950-2010			Chile 1950-2010		
	Deaths	Exposure	Rate	Deaths	Exposure	Rate	Deaths	Exposure	Rate
15-19	277052	273111277	0.0010	9776	5259979.01	0.0019	7214	5521684	0.0013
20-24	413198	269794760	0.0015	15300	5197169.29	0.0029	11303	5475437	0.0021
25-29	394947	262542163	0.0015	19271	5110187.07	0.0038	14698	5410021	0.0027

Table 7.2 continued from previous page

Age	Japan 1947-2010			Brazil 1950-2010			Chile 1950-2010		
	Deaths	Exposure	Rate	Deaths	Exposure	Rate	Deaths	Exposure	Rate
30-34	401713	254448032	0.0016	22746	5005110.72	0.0045	17653	5329257	0.0033
35-39	490686	242081752	0.0020	26799	4881710.39	0.0055	21659	5231678	0.0041
40-44	654780	227718389	0.0029	32698	4734077.92	0.0069	27990	5108706	0.0055
45-49	926154	214092337	0.0043	42383	4548122.86	0.0093	37685	4946057	0.0076
50-54	1311630	198173314	0.0066	56719	4302350.09	0.0132	51687	4724526	0.0109
55-59	1817504	177761616	0.0102	75524	3973644.98	0.0190	70674	4420666	0.0160
60-64	2374322	149329452	0.0159	98473	3539971.08	0.0278	94417	4009600	0.0235
65-69	2997508	120394293	0.0249	122525	2987016.18	0.0410	120694	3471727	0.0348
70-74	3552678	89746068	0.0396	141824	2321901.87	0.0611	143883	2806563	0.0513
75-79	3720263	58791250	0.0633	144580	1597653.265	0.0905	154595	2052258	0.0753
80+	6276285	48542814	0.1293	247812	1424579.483	0.1740	333484	2287302	0.1458

8 Appendix II

Table 8.1: Mortality rates computed from incidence rates, smoothed rates with respective confidence intervals and transformation to probabilities of death, single ages, BAF all and BAF Tertiary, 1943-2010

Age	BAF, 1943-2010							BAF, Tertiary-Higher (Doctors and Engineers), 1943-2010						
	L_x	D_x	m_{x+n}	Smoothed m_{x+n}	95%CI		q_{x+n}	L_x	D_x	m_{x+n}	Smoothed m_{x+n}	95%CI		q_{x+n}
35	13230	25	0.0019	0.0015	0.0017	0.0013	0.0015	1360	0	0.0000	0.0009	0.0016	0.0005	0.0009
36	13232	15	0.0011	0.0016	0.0018	0.0014	0.0016	1359	3	0.0022	0.0010	0.0016	0.0006	0.0010
37	13239	19	0.0014	0.0017	0.0020	0.0015	0.0017	1357	0	0.0000	0.0011	0.0017	0.0007	0.0010
38	13227	27	0.0020	0.0019	0.0021	0.0017	0.0019	1356	2	0.0015	0.0011	0.0017	0.0007	0.0011
39	13205	32	0.0024	0.0020	0.0022	0.0018	0.0020	1353	5	0.0037	0.0012	0.0018	0.0008	0.0012
40	13177	33	0.0025	0.0022	0.0024	0.0020	0.0022	1348	3	0.0022	0.0013	0.0019	0.0009	0.0013
41	13145	31	0.0024	0.0023	0.0025	0.0021	0.0023	1346	0	0.0000	0.0014	0.0019	0.0010	0.0014
42	13113	32	0.0024	0.0025	0.0027	0.0023	0.0025	1344	3	0.0022	0.0015	0.0020	0.0011	0.0015
43	13081	31	0.0024	0.0027	0.0029	0.0025	0.0027	1340	2	0.0015	0.0016	0.0021	0.0012	0.0016
44	13052	36	0.0028	0.0029	0.0031	0.0027	0.0029	1337	2	0.0015	0.0017	0.0022	0.0013	0.0017
45	13000	54	0.0042	0.0031	0.0033	0.0029	0.0031	1334	2	0.0015	0.0018	0.0024	0.0014	0.0018
46	12922	45	0.0035	0.0033	0.0036	0.0031	0.0033	1330	4	0.0030	0.0019	0.0025	0.0015	0.0019
47	12807	43	0.0034	0.0036	0.0038	0.0034	0.0036	1322	5	0.0038	0.0021	0.0026	0.0016	0.0021
48	12641	52	0.0041	0.0039	0.0041	0.0036	0.0039	1319	3	0.0023	0.0022	0.0028	0.0018	0.0022
49	12420	42	0.0034	0.0042	0.0044	0.0039	0.0041	1315	0	0.0000	0.0024	0.0030	0.0019	0.0024

Table 8.1 continued from previous page

Age	BAF, 1943-2010							BAF, Tertiary-Higher (Doctors and Engineers), 1943-2010						
	L_x	D_x	m_{x+n}	Smoothed m_{x+n}	95%CI		q_{x+n}	L_x	D_x	m_{x+n}	Smoothed m_{x+n}	95%CI		q_{x+n}
50	12196	47	0.0039	0.0045	0.0047	0.0042	0.0045	1313	3	0.0023	0.0026	0.0032	0.0021	0.0026
51	11884	71	0.0060	0.0048	0.0051	0.0046	0.0048	1301	3	0.0023	0.0028	0.0034	0.0022	0.0028
52	11496	59	0.0051	0.0052	0.0055	0.0049	0.0052	1288	1	0.0008	0.0030	0.0037	0.0024	0.0030
53	11045	61	0.0055	0.0056	0.0059	0.0053	0.0056	1266	4	0.0032	0.0032	0.0040	0.0026	0.0032
54	10586	59	0.0056	0.0060	0.0064	0.0057	0.0060	1242	6	0.0048	0.0035	0.0043	0.0029	0.0035
55	10152	59	0.0058	0.0065	0.0068	0.0062	0.0065	1219	4	0.0033	0.0038	0.0046	0.0031	0.0038
56	9764	76	0.0078	0.0070	0.0074	0.0066	0.0070	1189	3	0.0025	0.0041	0.0050	0.0034	0.0041
57	9377	68	0.0073	0.0076	0.0080	0.0072	0.0075	1158	4	0.0035	0.0045	0.0055	0.0038	0.0045
58	8948	73	0.0082	0.0082	0.0086	0.0078	0.0081	1129	7	0.0062	0.0049	0.0059	0.0041	0.0049
59	8488	64	0.0075	0.0088	0.0093	0.0084	0.0088	1099	4	0.0036	0.0054	0.0065	0.0045	0.0054
60	8085	68	0.0084	0.0095	0.0100	0.0091	0.0095	1054	4	0.0038	0.0059	0.0071	0.0050	0.0059
61	7719	88	0.0114	0.0103	0.0108	0.0098	0.0103	999	6	0.0060	0.0065	0.0077	0.0055	0.0065
62	7348	84	0.0114	0.0111	0.0117	0.0106	0.0111	947	8	0.0084	0.0071	0.0085	0.0060	0.0071
63	6970	88	0.0126	0.0121	0.0127	0.0115	0.0120	884	7	0.0079	0.0078	0.0093	0.0066	0.0078
64	6586	94	0.0143	0.0131	0.0137	0.0124	0.0130	830	10	0.0120	0.0086	0.0102	0.0073	0.0086
65	6228	80	0.0128	0.0142	0.0149	0.0135	0.0141	769	10	0.0130	0.0095	0.0112	0.0080	0.0095
66	5836	90	0.0154	0.0153	0.0161	0.0146	0.0152	708	4	0.0057	0.0105	0.0124	0.0089	0.0104
67	5436	97	0.0178	0.0166	0.0175	0.0158	0.0165	649	7	0.0108	0.0116	0.0136	0.0098	0.0115
68	5014	83	0.0166	0.0180	0.0189	0.0172	0.0179	599	6	0.0100	0.0127	0.0150	0.0108	0.0127

Table 8.1 continued from previous page

Age	BAF, 1943-2010							BAF, Tertiary-Higher (Doctors and Engineers), 1943-2010						
	L_x	D_x	m_{x+n}	Smoothed m_{x+n}	95%CI		q_{x+n}	L_x	D_x	m_{x+n}	Smoothed m_{x+n}	95%CI		q_{x+n}
69	4563	96	0.0210	0.0196	0.0206	0.0187	0.0194	558	11	0.0197	0.0140	0.0165	0.0119	0.0139
70	4082	86	0.0211	0.0213	0.0223	0.0203	0.0210	505	12	0.0238	0.0155	0.0182	0.0132	0.0154
71	3577	77	0.0215	0.0231	0.0243	0.0220	0.0228	453	8	0.0177	0.0171	0.0200	0.0146	0.0169
72	3124	75	0.0240	0.0251	0.0264	0.0239	0.0248	415	3	0.0072	0.0188	0.0221	0.0161	0.0187
73	2755	76	0.0276	0.0273	0.0287	0.0260	0.0269	380	7	0.0184	0.0208	0.0243	0.0177	0.0206
74	2426	67	0.0276	0.0297	0.0312	0.0282	0.0293	347	8	0.0230	0.0229	0.0269	0.0195	0.0226
75	2191	70	0.0319	0.0323	0.0341	0.0306	0.0318	318	12	0.0377	0.0253	0.0297	0.0215	0.0249
76	2000	72	0.0360	0.0352	0.0371	0.0333	0.0346	288	9	0.0312	0.0279	0.0328	0.0236	0.0275
77	1834	65	0.0354	0.0383	0.0406	0.0362	0.0376	266	4	0.0150	0.0307	0.0364	0.0259	0.0302
78	1685	60	0.0356	0.0417	0.0443	0.0393	0.0409	247	9	0.0364	0.0339	0.0404	0.0284	0.0333
79	1540	72	0.0467	0.0455	0.0485	0.0426	0.0445	228	12	0.0526	0.0373	0.0450	0.0309	0.0366
80	1392	72	0.0517	0.0496	0.0532	0.0463		206		0.0534	0.0411	0.0503	0.0336	
81	1253	68	0.0543	0.0541	0.0583	0.0501		190		0.0210	0.0453	0.0563	0.0365	
82	1107	78	0.0705	0.0589	0.0640	0.0543		175		0.0513	0.0499	0.0633	0.0394	
83	951	73	0.0768	0.0643	0.0703	0.0588		150		0.0467	0.0550	0.0714	0.0424	
84	817	51	0.0624	0.0701	0.0773	0.0635		129		0.0695	0.0606	0.0808	0.0455	

Source: SIGPES/DIRSA (2015)

Table 8.2: Death Probabilities for different life tables

Age	BR-EMS 2010	RP-2000	Preston-Codran	Civil Sevants 1993-2014	
	nqx			Secondary	Tertiary
35	0.00149	0.00077	0.00000	0.00297	0.00069
36	0.00157	0.00084	0.00000	0.00309	0.00076
37	0.00166	0.00090	0.00000	0.00323	0.00084
38	0.00176	0.00096	0.00000	0.00339	0.00092
39	0.00186	0.00102	0.00000	0.00358	0.00102
40	0.00198	0.00108	0.00000	0.00379	0.00112
41	0.00211	0.00114	0.00000	0.00403	0.00123
42	0.00225	0.00122	0.00000	0.00430	0.00135
43	0.00240	0.00130	0.00000	0.00460	0.00149
44	0.00256	0.00140	0.00000	0.00492	0.00164
45	0.00275	0.00151	0.00436	0.00529	0.00181
46	0.00295	0.00162	0.00479	0.00568	0.00199
47	0.00317	0.00173	0.00531	0.00612	0.00219
48	0.00341	0.00186	0.00584	0.00660	0.00241
49	0.00367	0.00200	0.00652	0.00711	0.00265
50	0.00396	0.00214	0.00711	0.00768	0.00291
51	0.00427	0.00245	0.00784	0.00830	0.00320
52	0.00462	0.00267	0.00877	0.00896	0.00353
53	0.00499	0.00292	0.00963	0.00969	0.00388

Table 8.2 continued from previous page

Age	BR-EMS 2010	RP-2000	Preston-Codran	Civil Sevants 1993-2014	
		nqx		Secondary	Tertiary
54	0.00541	0.00320	0.01067	0.01048	0.00427
55	0.00586	0.00362	0.01167	0.01133	0.00470
56	0.00635	0.00420	0.01294	0.01225	0.00517
57	0.00690	0.00469	0.01423	0.01325	0.00568
58	0.00749	0.00527	0.01570	0.01432	0.00625
59	0.00814	0.00595	0.01730	0.01549	0.00688
60	0.00886	0.00675	0.01891	0.01674	0.00756
61	0.00964	0.00768	0.02052	0.01810	0.00832
62	0.01049	0.00876	0.02289	0.01956	0.00915
63	0.01143	0.01001	0.02521	0.02113	0.01006
64	0.01246	0.01128	0.02758	0.02282	0.01106
65	0.01358	0.01274	0.03030	0.02463	0.01216
66	0.01481	0.01441	0.03254	0.02658	0.01337
67	0.01616	0.01608	0.03580	0.02868	0.01470
68	0.01763	0.01787	0.03908	0.03092	0.01615
69	0.01925	0.01980	0.04279	0.03332	0.01775
70	0.02102	0.02221	0.04672	0.03588	0.01950
71	0.02295	0.02457	0.05038	0.03863	0.02143
72	0.02508	0.02728	0.05594	0.04155	0.02354
73	0.02740	0.03039	0.06107	0.04467	0.02585

Table 8.2 continued from previous page

Age	BR-EMS 2010	RP-2000	Preston-Codran	Civil Sevants 1993-2014	
		nqx		Secondary	Tertiary
74	0.02994	0.03390	0.06667	0.04798	0.02838
75	0.03273	0.03783	0.07272	0.05150	0.03115
76	0.03578	0.04217	0.07970	0.05523	0.03418
77	0.03912	0.04691	0.08607	0.05918	0.03750
78	0.04278	0.05212	0.09465	0.06335	0.04113
79	0.04679	0.05793	0.10338	0.06775	0.04510
80				0.07238	0.04942
81				0.07724	0.05415
82				0.08233	0.05929
83				0.08765	0.06490
84				0.09320	0.07100