

Estimation of life tables for individuals with cerebral palsy in South Africa

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ABSTRACT

This paper presents an approach to estimating life tables for individuals diagnosed with cerebral palsy (CP) in South Africa. Background regarding the uncertainty when estimating mortality, and the need for establishment of a register for individuals with CP, may be found in Steel et al. (2019). The focus of this paper is to formulate a method to estimate full life tables, thereby highlighting the unique shape of the survival function for individuals with CP. Technical concepts that would be of interest primarily to life expectancy experts and actuaries working in the field of medical negligence litigation are presented in the paper. Other applications are however also possible.

KEYWORDS

Cerebral palsy, full life tables, future medical, loss of earnings

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1. BACKGROUND

A component of the medical negligence litigation process involves calculating the expected present value of future medical expenses to be incurred for the injured person. As part of this calculation, the expected mortality experience of that individual must be considered. This is currently performed in two stages:

- Firstly, a life expectancy expert is approached. This is usually a medical practitioner familiar with the published research on mortality of individuals with CP. The expert typically performs a clinical assessment of the individual. Based on the findings of the assessment together with reference to the chosen published research, a life expectancy estimate is proposed. This can be expressed as a percentage of normal life expectancy, where normal refers to general mortality of the South African population, or as the number of additional years the person is expected to live.
- Secondly, this estimate, together with details regarding future incidence and cost of expenses, are used by an actuary to calculate the expected present value of future medical expenses. The actuarial calculation is done by projecting the future expected expenses, where mortality in each future year is considered. The actuary uses own judgement to convert the expert opinion on life expectancy into a life table to be used in the calculation. The calculation for future loss of earnings requires similar considerations regarding expected mortality.

The above process highlights several areas where there is room for judgement, which often leads to different experts producing different results. Legal teams and the courts are then left to deliberate on using the different results. This paper considers the various approaches for each step in this process, with a focus on the second point related to formulation of life tables to be used by the actuary.

2. CHOICE OF PUBLISHED RESEARCH

Life tables are typically constructed by compiling data over time from a subset of the reference population before statistical methods are applied to formulate the final tables. In the context of this paper the data would relate to number of lives exposed and deaths for individuals diagnosed with CP in South Africa. Such data are not available; one has to look to research published outside South Africa, and then adjust such research for local application.

Various international publications are available that provide mortality estimates for individuals with CP. These studies are summarised succinctly in Plover (2019). The paper summarises the mortality statistics provided in the publications and gives details of the size of the respective sample populations. Further analysis is based only on the Californian study of Brooks et al. (2014), an approach that offers the following advantages:

- The Californian study is by a significant margin the largest international study, in terms of lives exposed and period.
- It is based on objective rating factors that can be relatively easily and reliably ascertained.
- It is already widely used in South Africa.

Other international studies are therefore not considered further in this paper.

3. SUMMARY OF THE CALIFORNIAN STUDY

Referring to their Californian study, Brooks et al. (2014) state:

The aim of the study was to determine survival probabilities and life expectancies for individuals with cerebral palsy based on data collected over a 28-year period in California.

This study showed, in line with previous studies in the region, that the most significant rating factors affecting mortality are mobility and feeding method. The authors of the Californian study provide summarised statistics based on their analysis of the data:

- Table 1 on page 3 provides a summary of the participant characteristics, for example, sample size and number of deaths for five age cohorts.
- Table 2 on page 4 provides the probabilities of survival for a 4-year-old child with CP to ages 10, 15, 20, 25 and 30.
- Table 3 on page 5 provides the life expectancies for individuals with CP aged 15, 30, 45 and 60.

The statistics in Tables 2 and 3 are provided for different mobility classifications and methods of feeding.

Access to the database used in the Californian study is ideally required to produce full life tables, however the data are not available. The next best approach is to extrapolate the summarised data in the published tables. The advantages of this approach are as follows:

- In the absence of a full life table for individuals with CP, the approach that is often currently used by actuaries is to adjust a standard table, such as the SALT 84–86 tables. The adjustments are made so that the resultant table produces the required summary statistic (typically a life expectancy). The extrapolation approach discussed in this paper produces a life table that more accurately reflects the mortality patterns at different ages for an individual with CP. Later in this paper, the impact on the expected present values of these different approaches is estimated.
- It allows for interim calculations to be done, if the mobility classification and method of feeding are known, before a life expectancy opinion can be sourced.
- A full life table, covering all ages, would allow for more accurate estimation of life expectancy for individuals at ages in between those published.

4. STATISTICS TO BE USED

4.1 Change in classification

Before statistics to be used to extrapolate life tables are selected, consideration is given to the probability that a child may transition between the categories provided in the Californian study.

Although the brain damage in CP is static, the expression varies with age. Rosenbaum et al. (2002) initially published gross motor development curves for CP individuals. This work was later expanded by Hanna et al. (2008) and numerous studies that attempt to find predictors of the future developmental trajectories of CP individuals (see for example Voorman et al., 2007, and Bartlett et al., 2010). The gross motor and feeding skills that the Californian study rely on are least stable for young CP individuals. The findings of these studies show that for most, the movement in the level of disability depends on the initial level of disability. For certain groups the level of disability reduces uniformly with age (i.e. more skills are acquired as the individual gets older). For other groups, there may be an increase in the level of disability following attainment of some peak level of ability (i.e. individuals lose skills). In some instances the probable trajectories in the skills are predictable.

Depending on the particular circumstances of the injured plaintiff, the research suggests that it may be worth waiting until approximately age 15 before a life expectancy opinion should be provided, because the level of disability at this age is more likely to remain stable for the duration of their remaining lifetime. The individual can then be placed into the relevant mobility and feeding category with little risk that this category may not be the correct one in future.

The studies by Hanna et al. (2008) and others are based on GMFCS level (Gross Motor Function Classification System, see Palisano et al., 1997), which does not map easily onto the feeding and mobility categories in the Californian study, used in this paper. Life expectancy experts however should be made aware of the research on developmental trajectories in CP and consider whether any adjustment for the future level of disability of an individual needs to be made.

For children under the age of 15, life expectancy experts should consider providing separate opinions on the child's current categorisation in terms of the Californian study, and the likely categorisation after age 15. A life table can then be formed by combining the survival probabilities for the categories using the techniques discussed below. For children after the age of 15, an opinion only needs to be provided as to the likely long-term classification, which would likely be based on the current abilities of the adolescent.

The possibility that CP individuals may change classification, which in turn may change their expected mortality experience, suggests that a multi-state type model may be appropriate, however this is not explored further in this paper.

4.2 STATISTICS USED FROM THE CALIFORNIAN STUDY

For the formulation of the life tables, the statistics from Table 2 of the Californian study are used below age 15, and the statistics from Table 3 of the Californian study are used from age 15 onwards. This also allows for the possibility that a child under age 15 may not currently be in the appropriate long-term category, as discussed in section 4.1, by facilitating the use of statistics from the Californian study for different categories before and after age 15.

The following can be noted about Tables 2 and 3 from the Californian study:

- The mobility categories in Tables 2 and 3 are not congruent.

- The feeding categories are the same in Tables 2 and 3, i.e. Tube Fed, Fed Orally by Others (FOBO) and Self Fed. The exception to this is for the Walks Unaided category in Table 3, which is not divided into any feeding categories – this is because individuals in this category are almost entirely self-feeding. There are also no self-feeding categories for the two categories who cannot roll/sit because this combination of skills is understandably rare.
- Table 3 distinguishes between males and females for three categories, whereas the data in Table 2 are not gender specific.

The combined statistics from Tables 2 and 3 that will be used are shown in Tables A and B.

TABLE A Statistics from Californian Study Table 2 – to be used below age 15

	6P4	11P4
Cannot lift head in the prone position		
Tube fed	75%	58%
FOBO	85%	73%
Self fed	97%	90%
Lifts head not chest in prone		
Tube fed	79%	66%
FOBO	89%	80%
Self fed	97%	92%
Partial rolling		
Tube fed	82%	71%
FOBO	93%	86%
Self fed	97%	95%
Full rolling		
Tube fed	90%	85%
FOBO	96%	93%
Self fed	99%	98%
Walks unaided		
Tube fed	96%	94%
FOBO	97%	97%
Self fed	100%	99%

The Walks Unaided and FOBO combination is rare in California but significantly more common in South Africa. This category needs special consideration but falls outside the scope of this paper.

TABLE B Statistics from Californian Study Table 3 – to be used after age 15

	e_{15}	e_{30}	e_{45}	e_{60}
Cannot lift head				
Tube fed	14	14	12	7
FOBO	18	19	14	10
Lifts head or chest				
Tube fed	18	14	12	7
FOBO	23	23	17	10
Rolls/sits				
Tube fed	27	18	12	7
FOBO female	37	32	21	10
FOBO male	33	28	18	10
Self fed female	48	37	25	16
Self fed male	45	33	22	12
Walks unaided				
Female	55	43	29	19
Male	52	39	25	15

Methods to produce a life table based on the statistics in Tables A and B are considered next.

5. FORMULATION OF A LIFE TABLE

5.1 Life table extrapolation techniques

There are multiple life tables that could be extrapolated from the statistics above, and there are various methods to produce such life tables. Some of the methods are summarised in Strauss et al. (2005).

Various methods were tested, including the PLE (proportional life expectancy) method, fitting of a Makeham-type formula and other simpler parametric formulae. The authors of the Californian study have used a different method for different age ranges. Furthermore, Strauss and Shavelle (1998) using non-overlapping cohorts aged 15, 30 and 45 years found that “the patterns of mortality over the subsequent 15 years are different for each group, contradicting the proportional hazards assumption”. This suggests that there is no uniform method that reliably predicts the complex age-specific mortality in CP individuals across the life table and this dictates a flexible approach to extrapolating life tables from the available data.

5.2 Extrapolating shape of life table from the Californian published data

5.2.1 AFTER AGE 15

A life table for persons aged 15 years or older is considered first, where only the life expectancy statistics provided in Table 3 on page 5 of the Californian study were used. The method used to extract a life table was as follows:

- A standard table was chosen as the Californian 2010 Life Table (see Barbieri and Wilmoth, 2019).

- From the standard table, values for e_{15} , e_{30} , e_{45} and e_{60} were derived.
- After consideration of the techniques in section 5.1, a relative risk approach was then followed. After age 60, a constant relative risk adjustment was made, i.e. a constant factor was applied to q_x from age 60 onward to produce the required e_{60} for each category. Between ages 45 and 60, the same constant was applied, but with a cumulative adjustment each year that increased as t decreased to produce the required e_{45} . This translates to a linear adjustment of q_x between ages 45 and 60, or a linear relative risk approach. Between ages 30 and 45, a similar linear adjustment was applied, from the absolute adjustment calculated for age 45, to solve for the required e_{30} . This step was similarly repeated to solve for the required e_{15} .

The adjustments made to the standard table q_x can be represented graphically (Figure 1) as follows for the Lifts Head or Chest and FOBO category.

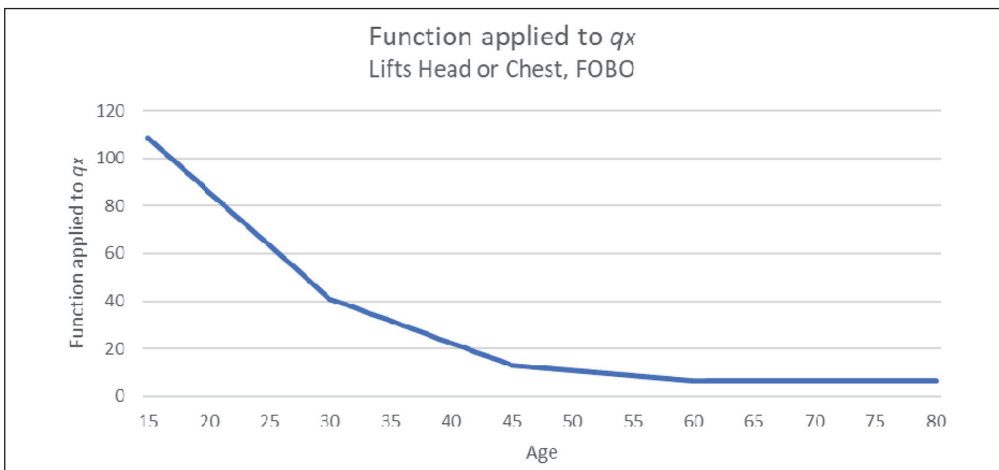


FIGURE 1 Adjustment function to q_x for a specific category

- The advantages of this approach are as follows:
- Allowing for separate adjustments between the age ranges provides the flexibility to align to the published statistics.
 - In comparison to a step function where the adjustment would be constant between the age bands, this method produces a smoother progression of q_x .
 - The method allows for some intuitive interpretation of how the mortality of individuals with CP compares with that of the general population. For example, in Figure 1, the adjustment is monotonically decreasing, which implies that the mortality for individuals with CP is initially much higher than that of the general population, but this increase reduces over time. This suggests that a method that applies a constant relative risk adjustment may not be appropriate, as the shape of a life table for a CP individual differs from the shape of a life table for a person in the general population.

The results of this exercise produced life tables from age 15 that matched the required remaining life expectancy as per Table 3 of the Californian study. The resultant survival function, ${}_tP_{15}$, for the Lifts Head or Chest, FOBO category is shown in Figure 2.

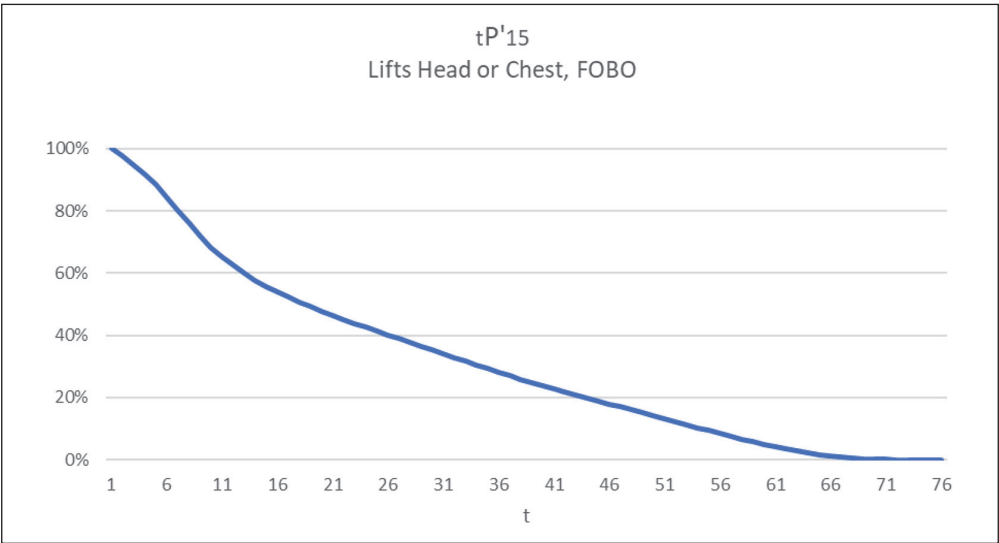


FIGURE 2 Survival function for a specific category

Initial checks were performed to ensure that the death rates were reasonable in absolute terms, and in terms of the rate of movement between ages. The analysis showed that the values for q_x for the Walks Unaided Males and Females were unrealistically low at ages 23 to 32, and in particular fell below zero at certain ages within this range. Further analysis showed that this was due to the linear adjustment made to q_x below age 45. To overcome this, constant adjustments were applied between ages 15 to 29 and 30 to 44, with the constants being chosen to produce a relatively smooth progression of q_x .

5.2.2 AGES 4 TO 15

As detailed in section 4.1, if waiting until the injured child is 15 is not possible, the data in Table 2 of the Californian study could be used to determine the survival probabilities up to age 15. Table 2 provided survival probabilities (${}_tP_4$) to ages 10 and 15.

A simple quadratic function was used to fit the log transformation of the provided survival statistics. Once transformed back, checks were performed on the resultant annual survival probabilities to ensure the probabilities were uniformly decreasing. This check failed only for the Walks Unaided FOBO Male and Female categories at ages 12 to 14 and 11 to 14 respectively. In this range, a linear survival function was fitted – there are likely to be few such cases in practice. Actuaries should consider a simple method to extrapolate survival probabilities based on the actual age of the child, for example a level q_x assumption that produces the required ${}_{(15-x)}P_{x^*}$

5.2.3 COMBINED TABLE BEFORE AND AFTER AGE 15

The survival probabilities in the above sections could simply be combined to produce a full life table for persons under age 15. This will require an opinion as to the child's category before and after age 15. Once the combined table is formed, checks should be done, particularly around age 15 to ensure a gradual progression of q_x . Simple smoothing, e.g. assuming a linear survival function between ages 12 and 18, could be considered by the actuary.

It is worth noting that any life table produced would apply to an individual in a specific disability category, and possibly a different disability category at age 15.

5.2.4 FURTHER SMOOTHING AND REASONABILITY CHECKS

The above method produces a crude life table based on the Californian data. In particular, it will later be shown that the shape implied is significantly different compared to the shape obtained by adjusting a standard table. While the overall method, and resultant difference in shape, has the most significant impact for quantum calculations, actuaries should consider applying other adjustments, based on features required of life tables, and other factors such as reasonability of the implied mortality rates between different categories.

To illustrate how such considerations could be applied, the following further adjustments were made to the crude q_x :

- Inspection of the q_x curve revealed that for most categories, a dip occurred prior to age 60. This is due to the nature of the linear relative risk method used to adjust the standard table rates. To overcome this, q_x was smoothed by applying a straight line from approximately age 42 until approximately age 60.
- To provide a reasonable blend of q_x for children younger than 15, q_x was smoothed around age 15 to produce a reasonable progression from the life tables produced up to age 15 and after age 15.
- For certain categories, the general method produced a lower q_x for higher functioning categories, which is not biologically possible. This occurred over limited ages, and a simple adjustment was made whereby the same q_x was used for both categories.

Whilst performing the above adjustments, the resultant impact on e_{15} , e_{30} , e_{45} and e_{60} was monitored to ensure that they still aligned to the Californian published statistics. It should be reiterated that, as rudimentary as some of the adjustments seem, they can be refined on an individual basis, and this should not detract from the more significant results regarding the general shape of the mortality curve for individuals with CP that the general method suggests.

The life tables and mortality rates produced using the method above for all categories are shown in Appendix A and B to this paper.

6. PRODUCTION OF A CP LIFE EXPECTANCY ESTIMATE

The focus of this paper is the production of life tables that reflect the unique survival probabilities of individuals with CP. This is in contrast to the production of a life expectancy

estimate, which ideally requires a combination of medical, actuarial, and possibly legal skills. However, to illustrate the impact of using different life tables, a brief discussion as to the formulation of the life expectancy estimate is presented below.

The formulation of the life expectancy opinion begins with consideration of the international studies available and extracting the estimate for the individual in question. As this estimate applies in a foreign territory, and typically for the “general CP population” in that territory, further adjustments are made. The adjustments discussed below assume the life expectancy estimate is also based on the Californian study, but the adjustments can be applied similarly to estimates derived from other international studies.

6.1 Other adjustments

In some instances, further adjustments may be applied to the resultant life table if the individual is expected to be exposed to lesser or greater mortality risks compared to the typical case in the category.

For example, an adjustment for low weight for age can be determined by applying the GMFCS level specific growth charts published by Brooks et al. (2011) where individuals in the high-risk zone may be expected to experience a reduction in their life expectancy of more than 30%. Other common conditions that may warrant downward adjustment is the presence of active seizure disorder, blindness, orthopaedic complications and incontinence and other comorbidities. In the lower functioning categories, good communication skills, ability to learn, and some hand use are examples of factors that improve survival probabilities. It should also be noted that such adjustment may vary by age range in the life table. There are various studies that illustrate how one could determine if such adjustment is necessary, but these fall out of the scope of this paper.

6.2 Adjusting to South African conditions

Adjustment also needs to be made to apply the life expectancy estimate in South Africa. There are various methods that could be used to make this adjustment. The method most used in South Africa, which is validated as a “reasonable choice” in the Californian study, is the Percentage of Normal method.

Under this method, the ratio of life expectancy in the different general populations is applied to adjust the life expectancy for the target group. For example, suppose that the life expectancy for a 10-year-old child with CP is 30 additional years in a Californian context. Next, suppose the life expectancy for a 10-year-old in the Californian and South African general population is 70 and 50 additional years respectively. Under this method, the life expectancy for such a 10-year-old child with CP in South Africa would then be estimated to be 21,4 additional years ($= 30 \times [50 / 70]$).

In order to apply this method, the life expectancy for the two general populations need to be calculated:

- The Californian general life expectancy was calculated from the Californian 2010 life table.

- The South African general life expectancy can be discussed at length. Actuaries and life expectancy experts should substantiate their own choice of life table in their individual opinions. For the sake of this publication, the *Quantum Yearbook* Life Table 3 (Koch, 2020) has been chosen.

This method produces an estimate of the life expectancy for an individual with CP in South Africa.

7. PRODUCTION OF SOUTH AFRICAN CP TABLES

At this stage, the following have been formulated:

- A life table applicable to a CP person in a Californian context.
- A life expectancy estimate for a CP person in South Africa with possible other adjustments.

To produce a life table to be applied in South Africa, it is recommended that the relevant life table developed above in a Californian context be used with an adjustment to the force of mortality, i.e. a constant relative risk method, to produce the required South African life expectancy. In the case of discrete life tables, this translates to raising the survival probabilities ${}_tP_x$ to some constant, with the constant being solved for by trial and error such that the life table yields the required e'_x . This method produces a life table with the required life expectancy and a shape suitable to individuals with CP.

The force of mortality adjustment method is currently used by most actuaries in South Africa; however the adjustment is made to a standard table. This assumes that the shape of mortality for a CP individual is similar to that of the general population. The customised life tables developed in this paper produce a shape more suitable to individuals with CP. A comparison of the life tables produced using a standard table and customised table is considered below.

8. COMPARISON OF METHODS TO PRODUCE LIFE TABLES

The standard table considered here is Life Table 3 from *Quantum Yearbook*, Koch (2020). The sample case that shall be considered relates to a female aged 15, assumed to be in the FOBO feeding category and Rolls/sits mobility category. We further assume that we have been provided with a life expectancy estimate of 32,5 additional years, i.e. $e'_{15} = 32,5$ for the specific individual in South Africa.

The unadjusted *Quantum Yearbook* Life Table 3 life expectancy is 59,3 additional years. A force of mortality adjustment of 846% is required to produce $e_{15}^{(SALT)} = 32,5$.

The customised life table produced in Section 5 above produces a life expectancy at age 15 of 37,4 additional years. A force of mortality adjustment of 36% is required to produce $e_{15}^{(ROLLS/SITS FOBO)} = 32,5$.

It is worth pointing out an obvious but interesting feature at this stage. The required adjustments to the force of mortality are far lower for the customised table than for the

standard table. This alludes to the customised table being more appropriate, i.e. it is more appropriate to use a life table that is based on individuals with CP, than it is to use a life table based on the relevant general population.

The shapes of the resultant survival function and mortality rate are shown in Figure 3.

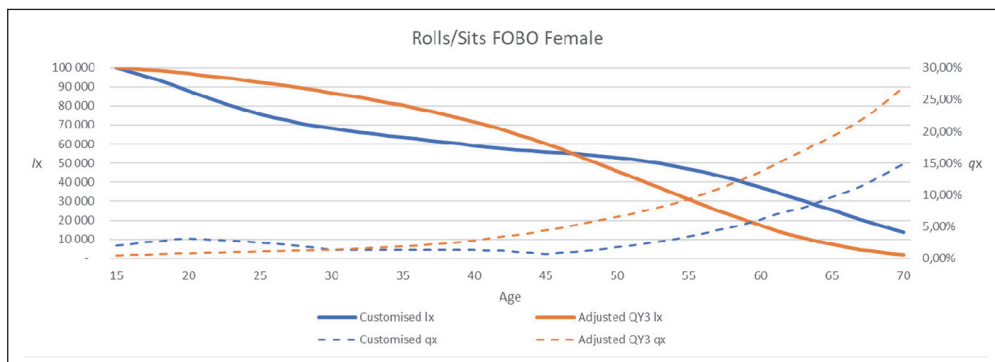


FIGURE 3 Survival functions and mortality rates for a specific category

The following observations are made:

- The probability of survival is initially lower under the customised curve compared to the standard curve. The curves cross at approximately age 47, after which the probability of survival is lower under the standard curve. It is worth reiterating that both curves produce the same life expectancy of 32,5 additional years.
- The extent of the misalignment of the curves will depend on the age of the individual. For older individuals of the same disability classification, the curves will be more closely aligned.

The above feature of initially lower survival probabilities under a customised curve appears for most disability categories, and a comparison of all categories is presented in Appendix C. Generally, there is a larger misalignment for the categories that are more severely impaired.

The impact of this difference in the shape of mortality on the quantum calculation is considered in the next section.

9. IMPACT ON THE EXPECTED PRESENT VALUE

9.1 Components of the expected present value calculation of future medical expenses

The expected present value (EPV) of future medical expenses is calculated as the product of three vectors:

- The incidence of future medical expenses.
- A function representing the impact of economic discounting, i.e. the net discount rate, typically 2,5%.
- The probability of survival.

An example of the proposed medical expenses, i.e. a list of required devices and treatment, is provided in the next section. Such a list is compiled based on the input of various medical experts such as a physiotherapist, occupational therapist and nurse. Alternatively, a list, devoid of duplicates, may be provided by the instructing attorney or advocate. Whilst the recommendations differ on a case-by-case basis, a general feature is that the expenses are higher earlier on and taper off as the individual gets older. This is due to the initial need for more intensive therapy and in some cases, provision for a special needs school which stops at age 18 or 21.

The economic discounting function also reduces over time, again placing greater emphasis on expenses required earlier on, and reducing the cost of expenses required at older ages. For example, at a 2,5% net discount rate, an expense of R1 000 required in one year produces a present value of R976, whereas an expense of R1 000 required in 10 years' time produces a present value of R781.

9.2 Impact of different life tables on the EPV of future medical expenses

This section demonstrates the impact on the EPV of the customised life tables compared to the adjusted standard life tables. Before this can be done, a sample of future medical recommendations, or “basket of goods” needs to be composed. This has been done with reference to actual matters where the authors provided expert reports, and was comprised of expenses to cover therapy, medical supplies, devices/items, caregiving, housing and school/institutional care.

The EPV of each of the expenses was calculated at a 2,5% net discount rate under the different life tables, as shown in Table C.

TABLE C Expected present value of future medical expenses

Item description	Amount, incidence, frequency	Present value: adjusted std life table	Present value: customised life table	% Change to customised
Therapy (first 2 years)	R5 500 every 1 month from now until age 17	R128 338	R127 789	−0.4%
Therapy (thereafter until age 21)	R4 500 every 1 month from age 17 until age 21	R191 552	R186 540	−2.6%
Therapy (after age 21)	R3 000 every 1 month from age 21 for life	R570 025	R531 925	−6.7%
Therapy (spread)	R56 500 in total evenly spread from now for life	R33 413	R29 529	−11.6%
Devices / items (regular)	R1 500 every 1 month from now for life	R383 865	R362 994	−5.4%
Devices / items (every 5 years)	R15 000 every 5 years from now for life	R71 534	R68 082	−4.8%
Medical supplies (regular)	R5 000 every 1 month from now for life	R1 279 549	R1 209 980	−5.4%
Continued overleaf				

Item description	Amount, incidence, frequency	Present value: adjusted std life table	Present value: customised life table	% Change to customised
Medical supplies (every 5 years)	R3 000 every 5 years from now for life	R14 307	R13 616	-4.8%
Devices / items (once off)	R27 000 once off now	R27 000	R27 000	0.0%
Therapy (once off)	R63 000 once off now	R63 000	R63 000	0.0%
Caregiving (until age 18)	R10 000 every 1 month from now until age 18	R344 850	R342 323	-0.7%
Caregiving (after age 18)	R13 500 every 1 month from age 18 until age 40	R2 267 182	R1 954 000	-13.8%
Housing (once off)	R300 000 once off now	R300 000	R300 000	0.0%
Vehicle (every 5 years)	R250 000 every 5 years from now for life	R1 192 237	R1 134 692	-4.8%
School (until age 18)	R4 000 every 1 month from now until age 18	R137 940	R136 929	-0.7%
Institution (last 5 years, age 40)	R10 000 every 1 month from age 40 for life	R534 854	R630 229	17.8%
	Control Total	R7 539 646	R7 118 628	-5.6%

The total EPV using the customised life table is 5,6% lower compared to using the adjusted standard life table. This is due to the incidence of expenses after economic discounting being skewed toward the earlier ages, where the probability of survival is lower under the customised life table. This is illustrated in Figure 4.

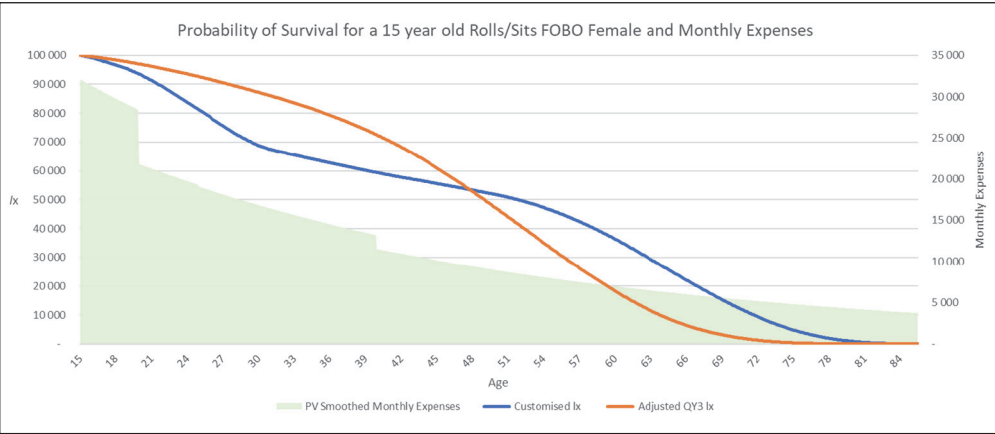


FIGURE 4 Survival probabilities and monthly expenses for a specific category

From the above graph and table, we note the following:

- The present value of expenses decreases over time. This is largely due to the impact of economic discounting.

- Expenses are higher when the probability of survival is lower under the Customised Life Table. By the time the life table survival curves cross, a significant portion of the expenses have already been accounted for. This results in the final present value of expenses being lower.
- The converse of the above observation can be confirmed by noting the movement for individual items required later in life, for example the EPV of being placed in an institution, the last item in Table C, which shows a 17,8% increase as it is only required from age 40.

9.3 Impact of different life tables on loss of earnings

The future medical expenses component is typically the most significant head of damage financially in CP medical negligence litigation. However, the customised life tables should similarly be applied to the loss of earnings calculation. Due to the delay in the loss being incurred, the impact of the difference in the shape of the respective life tables may be different to the impact observed for future medical expenses.

In our example of a 15-year old female child, the loss would only start to be incurred in five years' time, assuming she would have started working at age 20. To quantify the impact, the loss of earnings was calculated assuming that, had the alleged medical negligence not occurred, the plaintiff would have started work at the Paterson A1 level, with earnings increasing in a straight line until reaching Paterson B1 at age 45, with inflationary increases only thereafter until retirement at age 65. Median package earnings were used from *Quantum Yearbook 2020*. We assumed the plaintiff will not be able to work having regard to the alleged negligence. The loss of earnings, before contingency deductions, was calculated to be R2,26m under the Adjusted Standard Table and R2,44m under the Extrapolated Life Table, a decrease of 7,1%.

The impact on the loss of earnings varies depending on the age of the plaintiff, the level of disability and the term structure of projected earnings. For some matters, the loss of earnings may increase under the customised life tables.

9.4 Impact for other disability classifications

The above feature is similar for the other disability classifications, i.e. using an extrapolated life table produces a reduction in the EPV of future medical expenses and an increase or decrease in loss of earnings. The extent of the difference also depends on the term structure of the cashflows and age of the person.

10. CONCLUSION

This paper presents a method to produce life tables for persons with CP in South Africa, based on the Californian study. It highlights the difference in shape of the life table for individuals with CP compared with the general population.

Although the discussion has presupposed that a life expectancy opinion has already been provided, the tables may initially be used to derive the base life expectancy

in a Californian context. This would avoid the need for medical experts to estimate life expectancies for ages between those published in the Californian study. An adjustment can then be made to apply the results in a South African context. Further adjustment for other evidenced-based and subjective factors may be made by a medical expert.

Once the life expectancy opinion is available, it is recommended that actuaries consider the methodology presented in this paper to develop a customised life table for the quantum calculations, such as the tables provided in Appendix A and B. In most cases the customised life tables show some variation in the survival probabilities compared to using an adjusted standard table, for the same life expectancy. In the example shown, using the customised life table allows for the lower probability of survival at earlier ages and results in a reduction in the EPV of future medical expenses and loss of earnings.

REFERENCES

- Barbieri, M & Wilmoth, J (2019). United States mortality database. <https://usa.mortality.org/uploads/lifetables/lifetables.zip> (retrieved 6 July 2019)
- Bartlett, DJ, Hanna, SE, Avery, L, Stevenson, RD & Galuppi, B (2010). Correlates of decline in gross motor capacity in adolescents with cerebral palsy in Gross Motor Function Classification System levels III to V: an exploratory study. *Developmental Medicine & Child Neurology* 52(7), 155–160
- Brooks, JC, Day, SM, Shavelle, RM & Strauss, DJ (2011). Low weight, morbidity, and mortality in children with cerebral palsy: new clinical growth charts. *Pediatrics* 128(2), 299–307
- Brooks, JC, Strauss, DJ, Shavelle, RM, Tran, LM, Rosenbloom, L & Wu, YW (2014). Recent trends in cerebral palsy survival. Part II: individual survival prognosis. *Developmental Medicine & Child Neurology* 56(11), 1065–1071
- Hanna, SE, Bartlett, DJ, Rivard, LM & Russel, DJ (2008). Reference curves for the gross motor function measure: percentiles for clinical description and tracking over time among children with cerebral palsy. *Physical Therapy* 88(5), 596–607
- Koch, RJ (2020). *Quantum Yearbook (2020)*. Van Zyl, Rudd and Associates SA (Pty) Ltd.
- Palisano, RJ, Rosenbaum, PL, Walter, SD, Russell, DJ, Wood, EP & Galuppi, BE (1997). Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Physical Therapy*, 39, 214–223
- Plover, C (2019). Life expectancies for individuals with cerebral palsy. Cumpston Sarjeant Publications, 1–16
- Rosenbaum, PL, Walter, SD, Hanna, SE & Palisano, R (2002). Prognosis for gross motor function in cerebral palsy: creation of motor development curves. *The Journal of the American Medical Association* 288(11), 1357–1363
- Steel, SJ, Botha, AS & Khalawan T (2019). Cerebral palsy and delictual compensation – is there a need for a register? *De Rebus* 599, 14–16

- Strauss, DJ & Shavelle, RM (1998). Life expectancy of adults with cerebral palsy. *Developmental Medicine & Child Neurology* 1998 (40), 369–375
- Strauss, DJ, Vachon, PJ & Shavelle, RM (2005). Estimation of future mortality rates and life expectancy in chronic medical conditions. *Journal of Insurance Medicine* 37(1), 20–34
- Voorman, JM, Dallmeijer, AJ, Knol, DL, Lankhorst, GJ & Becher G (2007). Prospective longitudinal study of gross motor function in children with cerebral palsy. *Archives of Physical Medicine and Rehabilitation* 88(7), 871–876

APPENDIX A

Customised life tables from age 15

Sample customised CP life tables applicable in California – l_x from age 15

l_x	Cannot lift head		Lifts head or chest		Rolls/Sits					Walks unaided	
	Tube fed	FOBO	Tube fed	FOBO	Tube fed	FOBO Female	FOBO Male	Self fed Female	Self fed Male	Female	Male
15	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000
16	94 869	96 712	96 948	97 590	99 084	99 383	98 832	99 475	99 784	99 824	99 824
17	90 002	92 496	93 989	94 612	98 176	98 473	97 192	98 905	99 569	99 649	99 649
18	84 709	87 478	91 121	91 724	97 277	97 571	95 137	98 262	99 354	99 473	99 473
19	78 830	81 999	87 835	88 417	96 245	96 536	92 757	97 590	99 140	99 299	99 299
20	72 533	76 228	84 001	84 557	94 912	95 199	90 144	96 865	98 745	99 124	99 124
21	66 209	70 521	79 787	80 315	93 296	93 578	87 458	96 112	98 258	98 950	98 950
22	60 507	65 452	75 623	76 124	91 540	91 817	84 982	95 387	97 724	98 776	98 776
23	55 290	60 886	71 460	71 934	89 619	89 890	82 664	94 695	97 131	98 602	98 602
24	50 690	56 924	67 458	68 376	87 608	87 873	80 598	94 036	96 506	98 429	98 429
25	46 660	53 516	63 649	65 242	85 533	85 792	78 788	93 412	95 861	98 256	98 256
26	43 099	50 568	60 006	62 466	83 391	83 643	77 174	92 849	95 185	98 083	98 083
27	39 870	47 959	56 443	59 952	81 138	81 384	75 716	92 327	94 465	97 910	97 910
28	37 035	45 733	53 078	57 756	78 856	79 349	74 453	91 865	93 729	97 738	97 738
29	34 457	43 779	49 914	55 781	76 479	77 568	73 332	91 456	92 954	97 566	97 566
30	32 067	42 043	46 938	53 980	73 964	75 905	72 309	91 114	92 109	97 395	97 395
31	29 868	40 526	44 140	52 360	71 335	74 766	71 407	90 837	91 207	97 224	97 224
32	27 832	39 049	41 508	50 791	68 774	73 983	70 498	90 540	90 311	97 053	97 053
33	25 946	37 610	39 033	49 269	66 275	73 208	69 585	90 215	89 424	96 814	96 882
34	24 212	36 217	36 706	47 804	63 853	72 458	68 666	89 869	88 545	96 525	96 712
35	22 631	34 878	34 518	46 405	61 525	71 697	67 772	89 480	87 705	96 186	96 542
36	21 197	33 599	32 460	45 079	59 298	70 956	66 893	89 058	86 895	95 797	96 372
37	19 887	32 364	30 453	43 809	57 146	70 229	66 019	88 595	86 105	95 360	96 203
38	18 658	31 141	28 571	42 564	55 012	69 502	65 128	88 075	85 317	94 875	95 947
39	17 510	29 930	26 814	41 346	52 897	68 781	64 221	87 489	84 534	94 342	95 607
40	16 440	28 729	25 175	40 123	50 799	68 082	63 283	86 838	83 745	93 762	95 182
41	15 430	27 520	23 629	38 899	48 682	67 400	62 297	86 101	82 938	93 137	94 674
42	14 496	26 319	22 198	37 675	46 578	66 747	61 277	85 271	82 129	92 467	94 084
43	13 638	25 128	20 885	36 454	44 487	66 137	60 216	84 335	81 316	91 753	93 413
44	12 812	23 970	19 619	35 238	42 453	65 513	59 116	83 324	80 505	90 996	92 664

45	12 017	22 814	18 402	34 030	40 420	64 877	57 952	82 258	79 682	90 198	91 837
46	11 255	21 693	17 235	32 830	38 444	64 229	56 750	81 140	78 873	89 359	90 936
47	10 525	20 563	16 117	31 642	36 423	63 569	55 465	79 972	77 979	88 481	89 962
48	9 827	19 474	15 049	30 467	34 385	62 898	54 100	78 758	76 995	87 565	88 918
49	9 162	18 426	14 030	29 306	32 336	62 216	52 669	77 498	75 925	86 612	87 807
50	8 528	17 419	13 060	28 162	30 326	61 523	51 193	76 197	74 780	85 625	86 630
51	7 927	16 451	12 139	27 036	28 333	60 716	49 654	74 857	73 540	84 603	85 393
52	7 356	15 524	11 265	25 930	26 395	59 796	48 070	73 480	72 212	83 549	84 096
53	6 816	14 635	10 438	24 844	24 528	58 751	46 460	72 070	70 808	82 465	82 744
54	6 306	13 784	9 657	23 780	22 724	57 582	44 795	70 630	69 294	81 351	81 339
55	5 826	12 972	8 921	22 739	20 985	56 269	43 084	69 161	67 671	80 209	79 886
56	5 373	12 196	8 228	21 723	19 313	54 807	41 314	67 668	65 918	79 041	78 386
57	4 948	11 456	7 578	20 731	17 724	53 200	39 503	66 153	64 042	77 848	76 845
58	4 550	10 751	6 968	19 765	16 232	51 438	37 677	64 619	62 062	76 633	75 266
59	4 177	10 080	6 397	18 825	14 846	49 524	35 852	63 069	59 988	75 396	73 651
60	3 829	9 442	5 864	17 912	13 525	47 473	34 015	61 506	57 849	74 140	72 006
61	3 505	8 837	5 367	17 026	12 272	45 278	32 177	59 932	55 667	72 865	70 222
62	3 179	8 263	4 868	16 102	11 090	42 942	30 349	58 351	53 388	71 574	68 335
63	2 861	7 719	4 381	15 164	9 981	40 543	28 540	56 765	51 049	70 268	66 368
64	2 555	7 204	3 912	14 217	8 913	38 080	26 735	55 176	48 675	68 949	64 342
65	2 259	6 717	3 459	13 256	7 881	35 555	24 914	53 588	46 237	67 619	62 226
66	1 973	6 221	3 022	12 278	6 884	32 969	23 062	52 002	43 710	66 278	59 993
67	1 706	5 730	2 613	11 309	5 952	30 370	21 241	50 335	41 173	64 855	57 706
68	1 457	5 242	2 231	10 345	5 083	27 762	19 442	48 576	38 609	63 336	55 347
69	1 224	4 754	1 875	9 381	4 271	25 135	17 647	46 706	35 988	61 703	52 880
70	1 012	4 272	1 549	8 431	3 529	22 536	15 881	44 742	33 339	59 964	50 324
71	821	3 803	1 257	7 504	2 864	19 985	14 166	42 681	30 692	58 114	47 700
72	653	3 348	1 000	6 608	2 278	17 513	12 506	40 534	28 048	56 155	45 002
73	507	2 911	776	5 745	1 768	15 138	10 909	38 297	25 414	54 079	42 227
74	382	2 494	585	4 921	1 333	12 870	9 381	35 963	22 796	51 870	39 371
75	279	2 101	427	4 146	973	10 748	7 937	33 551	20 217	49 539	36 446
76	196	1 737	300	3 427	684	8 790	6 592	31 065	17 699	47 080	33 465
77	132	1 406	202	2 774	460	7 026	5 365	28 529	15 276	44 505	30 457
78	85	1 111	130	2 193	295	5 474	4 266	25 966	12 975	41 826	27 445
79	51	854	78	1 686	178	4 130	3 307	23 372	10 831	39 027	24 467
80	29	636	44	1 256	100	3 003	2 487	20 778	8 856	36 124	21 537
81	15	456	23	899	51	2 082	1 805	18 185	7 069	33 104	18 685
82	7	312	10	615	24	1 365	1 256	15 639	5 490	29 999	15 943
83	3	201	4	397	9	835	829	13 166	4 116	26 820	13 324

84	1	121	1	238	3	467	512	10 808	2 958	23 602	10 863
85	0	67	0	132	1	234	293	8 617	2 027	20 397	8 617
86	0	33	0	66	0	104	153	6 664	1 315	17 299	6 630
87	0	15	0	29	0	39	70	4 963	792	14 341	4 900
88	—	5	—	11	—	11	28	3 536	442	11 577	3 476
89	—	2	—	3	—	2	9	2 395	226	9 074	2 359
90	—	0	—	1	—	0	2	1 531	104	6 881	1 522
91	—	0	—	0	—	0	0	908	41	5 006	919
92	—	0	—	0	—	—	0	496	14	3 484	517
93	—	—	—	—	—	—	—	245	4	2 301	264
94	—	—	—	—	—	—	—	108	1	1 437	122
95	—	—	—	—	—	—	—	41	0	841	50
96	—	—	—	—	—	—	—	13	0	458	18
97	—	—	—	—	—	—	—	3	—	230	6
98	—	—	—	—	—	—	—	1	—	105	1
99	—	—	—	—	—	—	—	0	—	43	0
100	—	—	—	—	—	—	—	0	—	16	0

Sample customised CP life tables applicable in California – q_x from age 15

q_x	Cannot lift head		Lifts head or chest		Rolls/sits					Walks unaided	
	Tube fed	FOBO	Tube fed	FOBO	Tube fed	FOBO female	FOBO male	Self fed female	Self fed male	Female	Male
15	5.13%	3.29%	3.05%	2.41%	0.92%	0.62%	1.17%	0.52%	0.22%	0.18%	0.18%
16	5.13%	4.36%	3.05%	3.05%	0.92%	0.92%	1.66%	0.57%	0.22%	0.18%	0.18%
17	5.88%	5.42%	3.05%	3.05%	0.92%	0.92%	2.11%	0.65%	0.22%	0.18%	0.18%
18	6.94%	6.26%	3.61%	3.61%	1.06%	1.06%	2.50%	0.68%	0.22%	0.18%	0.18%
19	7.99%	7.04%	4.37%	4.37%	1.39%	1.39%	2.82%	0.74%	0.40%	0.18%	0.18%
20	8.72%	7.49%	5.02%	5.02%	1.70%	1.70%	2.98%	0.78%	0.49%	0.18%	0.18%
21	8.61%	7.19%	5.22%	5.22%	1.88%	1.88%	2.83%	0.75%	0.54%	0.18%	0.18%
22	8.62%	6.98%	5.50%	5.50%	2.10%	2.10%	2.73%	0.73%	0.61%	0.18%	0.18%
23	8.32%	6.51%	5.60%	4.95%	2.24%	2.24%	2.50%	0.70%	0.64%	0.18%	0.18%
24	7.95%	5.99%	5.65%	4.58%	2.37%	2.37%	2.25%	0.66%	0.67%	0.18%	0.18%
25	7.63%	5.51%	5.72%	4.26%	2.50%	2.50%	2.05%	0.60%	0.71%	0.18%	0.18%
26	7.49%	5.16%	5.94%	4.02%	2.70%	2.70%	1.89%	0.56%	0.76%	0.18%	0.18%
27	7.11%	4.64%	5.96%	3.66%	2.81%	2.50%	1.67%	0.50%	0.78%	0.18%	0.18%
28	6.96%	4.27%	5.96%	3.42%	3.02%	2.24%	1.51%	0.45%	0.83%	0.18%	0.18%
29	6.94%	3.97%	5.96%	3.23%	3.29%	2.14%	1.40%	0.37%	0.91%	0.18%	0.18%
30	6.86%	3.61%	5.96%	3.00%	3.55%	1.50%	1.25%	0.30%	0.98%	0.18%	0.18%
31	6.82%	3.64%	5.96%	3.00%	3.59%	1.05%	1.27%	0.33%	0.98%	0.18%	0.18%
32	6.78%	3.69%	5.96%	3.00%	3.63%	1.05%	1.29%	0.36%	0.98%	0.25%	0.18%
33	6.69%	3.71%	5.96%	2.97%	3.65%	1.02%	1.32%	0.38%	0.98%	0.30%	0.18%
34	6.53%	3.70%	5.96%	2.93%	3.65%	1.05%	1.30%	0.43%	0.95%	0.35%	0.18%
35	6.33%	3.67%	5.96%	2.86%	3.62%	1.03%	1.30%	0.47%	0.92%	0.40%	0.18%
36	6.18%	3.68%	6.18%	2.82%	3.63%	1.02%	1.31%	0.52%	0.91%	0.46%	0.18%
37	6.18%	3.78%	6.18%	2.84%	3.73%	1.03%	1.35%	0.59%	0.91%	0.51%	0.27%
38	6.15%	3.89%	6.15%	2.86%	3.84%	1.04%	1.39%	0.67%	0.92%	0.56%	0.35%
39	6.11%	4.01%	6.11%	2.96%	3.97%	1.02%	1.46%	0.74%	0.93%	0.61%	0.44%
40	6.14%	4.21%	6.14%	3.05%	4.17%	1.00%	1.56%	0.85%	0.96%	0.67%	0.53%
41	6.06%	4.36%	6.06%	3.15%	4.32%	0.97%	1.64%	0.96%	0.98%	0.72%	0.62%
42	5.92%	4.53%	5.92%	3.24%	4.49%	0.91%	1.73%	1.10%	0.99%	0.77%	0.71%
43	6.06%	4.61%	6.06%	3.34%	4.57%	0.94%	1.83%	1.20%	1.00%	0.82%	0.80%
44	6.20%	4.82%	6.20%	3.43%	4.79%	0.97%	1.97%	1.28%	1.02%	0.88%	0.89%
45	6.34%	4.91%	6.34%	3.52%	4.89%	1.00%	2.07%	1.36%	1.02%	0.93%	0.98%
46	6.49%	5.21%	6.49%	3.62%	5.26%	1.03%	2.26%	1.44%	1.13%	0.98%	1.07%
47	6.63%	5.30%	6.63%	3.71%	5.59%	1.06%	2.46%	1.52%	1.26%	1.04%	1.16%
48	6.77%	5.38%	6.77%	3.81%	5.96%	1.08%	2.65%	1.60%	1.39%	1.09%	1.25%

49	6.91%	5.47%	6.91%	3.90%	6.21%	1.11%	2.80%	1.68%	1.51%	1.14%	1.34%
50	7.05%	5.55%	7.05%	4.00%	6.57%	1.31%	3.01%	1.76%	1.66%	1.19%	1.43%
51	7.20%	5.64%	7.20%	4.09%	6.84%	1.51%	3.19%	1.84%	1.81%	1.25%	1.52%
52	7.34%	5.72%	7.34%	4.19%	7.08%	1.75%	3.35%	1.92%	1.95%	1.30%	1.61%
53	7.48%	5.81%	7.48%	4.28%	7.35%	1.99%	3.58%	2.00%	2.14%	1.35%	1.70%
54	7.62%	5.90%	7.62%	4.38%	7.65%	2.28%	3.82%	2.08%	2.34%	1.40%	1.79%
55	7.77%	5.98%	7.77%	4.47%	7.97%	2.60%	4.11%	2.16%	2.59%	1.46%	1.88%
56	7.91%	6.07%	7.91%	4.57%	8.23%	2.93%	4.38%	2.24%	2.85%	1.51%	1.97%
57	8.05%	6.15%	8.05%	4.66%	8.42%	3.31%	4.62%	2.32%	3.09%	1.56%	2.06%
58	8.19%	6.24%	8.19%	4.76%	8.54%	3.72%	4.84%	2.40%	3.34%	1.61%	2.15%
59	8.33%	6.33%	8.33%	4.85%	8.90%	4.14%	5.12%	2.48%	3.57%	1.67%	2.23%
60	8.48%	6.41%	8.48%	4.94%	9.27%	4.62%	5.40%	2.56%	3.77%	1.72%	2.48%
61	9.30%	6.50%	9.30%	5.42%	9.63%	5.16%	5.68%	2.64%	4.09%	1.77%	2.69%
62	9.99%	6.58%	9.99%	5.83%	9.99%	5.59%	5.96%	2.72%	4.38%	1.82%	2.88%
63	10.70%	6.67%	10.70%	6.24%	10.70%	6.07%	6.33%	2.80%	4.65%	1.88%	3.05%
64	11.58%	6.76%	11.58%	6.76%	11.58%	6.63%	6.81%	2.88%	5.01%	1.93%	3.29%
65	12.65%	7.38%	12.65%	7.38%	12.65%	7.27%	7.43%	2.96%	5.47%	1.98%	3.59%
66	13.54%	7.90%	13.54%	7.90%	13.54%	7.88%	7.90%	3.21%	5.81%	2.15%	3.81%
67	14.60%	8.52%	14.60%	8.52%	14.60%	8.59%	8.47%	3.49%	6.23%	2.34%	4.09%
68	15.97%	9.32%	15.97%	9.32%	15.97%	9.46%	9.23%	3.85%	6.79%	2.58%	4.46%
69	17.37%	10.13%	17.37%	10.13%	17.37%	10.34%	10.01%	4.21%	7.36%	2.82%	4.83%
70	18.84%	10.99%	18.84%	10.99%	18.84%	11.32%	10.80%	4.61%	7.94%	3.09%	5.21%
71	20.48%	11.95%	20.48%	11.95%	20.48%	12.37%	11.71%	5.03%	8.61%	3.37%	5.66%
72	22.37%	13.05%	22.37%	13.05%	22.37%	13.56%	12.77%	5.52%	9.39%	3.70%	6.17%
73	24.58%	14.34%	24.58%	14.34%	24.58%	14.98%	14.01%	6.10%	10.30%	4.08%	6.76%
74	26.99%	15.75%	26.99%	15.75%	26.99%	16.49%	15.39%	6.71%	11.32%	4.49%	7.43%
75	29.73%	17.34%	29.73%	17.34%	29.73%	18.22%	16.94%	7.41%	12.46%	4.96%	8.18%
76	32.68%	19.06%	32.68%	19.06%	32.68%	20.07%	18.62%	8.16%	13.69%	5.47%	8.99%
77	35.91%	20.95%	35.91%	20.95%	35.91%	22.09%	20.48%	8.99%	15.06%	6.02%	9.89%
78	39.61%	23.10%	39.61%	23.10%	39.61%	24.55%	22.48%	9.99%	16.53%	6.69%	10.85%
79	43.78%	25.54%	43.78%	25.54%	43.78%	27.29%	24.80%	11.10%	18.24%	7.44%	11.98%
80	48.70%	28.41%	48.70%	28.41%	48.70%	30.67%	27.43%	12.48%	20.17%	8.36%	13.24%
81	54.18%	31.61%	54.18%	31.61%	54.18%	34.42%	30.39%	14.00%	22.35%	9.38%	14.67%
82	60.77%	35.45%	60.77%	35.45%	60.77%	38.87%	34.02%	15.81%	25.02%	10.59%	16.43%
83	68.41%	39.91%	68.41%	39.91%	68.41%	44.03%	38.27%	17.91%	28.14%	12.00%	18.47%
84	76.85%	44.83%	76.85%	44.83%	76.85%	49.83%	42.82%	20.27%	31.49%	13.58%	20.67%
85	85.69%	49.98%	85.69%	49.99%	85.69%	55.72%	47.77%	22.67%	35.12%	15.19%	23.06%
86	96.52%	56.30%	96.52%	56.30%	96.52%	62.74%	54.05%	25.52%	39.74%	17.10%	26.09%
87	100.00%	63.00%	100.00%	63.00%	100.00%	70.70%	60.17%	28.76%	44.24%	19.27%	29.05%

88	100.00%	70.14%	100.00%	70.14%	100.00%	79.32%	66.56%	32.27%	48.94%	21.62%	32.13%
89	100.00%	77.88%	100.00%	77.88%	100.00%	88.70%	73.54%	36.08%	54.07%	24.18%	35.51%
90	100.00%	87.18%	100.00%	87.19%	100.00%	99.94%	82.08%	40.66%	60.35%	27.24%	39.62%
91	100.00%	96.58%	100.00%	96.59%	100.00%	100.00%	90.56%	45.40%	66.58%	30.42%	43.72%
92	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	50.65%	74.43%	33.94%	48.87%
93	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	56.03%	81.85%	37.54%	53.75%
94	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	61.93%	89.77%	41.50%	58.95%
95	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	67.93%	97.43%	45.51%	63.98%
96	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	74.40%	100.00%	49.85%	69.20%
97	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	80.97%	100.00%	54.25%	74.06%
98	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	87.98%	100.00%	58.95%	79.64%
99	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	95.18%	100.00%	63.77%	85.28%
100	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Statistics from above table for ages 15 and older for comparison to Californian study:

	Cannot lift head		Lifts head or chest		Rolls/Sits					Walks unaided	
	Tube fed	FOBO	Tube fed	FOBO	Tube fed	FOBO Female	FOBO Male	Self fed Female	Self fed Male	Female	Male
e'15	14	18	18	23	27	37	33	48	45	55	52
e'30	14	19	14	23	18	32	28	37	33	42*	39
e'45	11*	14	11*	17	12	21	18	25	22	29	25
e'60	7	10	7	10	7	10	10	16	12	19	15

The statistics align to the Californian study Table 3 for all categories and ages, except where indicated by * the life expectancies are different by 1 year.

APPENDIX B

Customised life tables from ages 4 to 15

Sample customised CP life tables applicable in California – l_x from age 4 to 15

l_x	Cannot lift head		Lifts head or chest		Partial rolling			Full rolling			Walks unaided		
	Tube fed	FOBO	Tube fed	FOBO	Tube fed	FOBO	Self fed	Tube fed	FOBO	Self fed	Tube fed	FOBO	Self fed
4	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000	100 000
5	95 469	97 476	96 002	98 161	96 559	98 958	99 453	97 986	99 301	99 849	99 205	99 447	99 947
6	91 085	94 958	92 220	96 323	93 309	97 863	98 924	96 120	98 616	99 691	98 463	98 943	99 882
7	86 848	92 449	88 640	94 487	90 238	96 717	98 415	94 394	97 943	99 528	97 772	98 487	99 805
8	82 756	89 951	85 251	92 653	87 336	95 524	97 925	92 802	97 283	99 358	97 132	98 078	99 716
9	78 808	87 467	82 041	90 824	84 593	94 284	97 453	91 340	96 635	99 182	96 542	97 716	99 614
10	75 000	85 000	79 000	89 000	82 000	93 000	97 000	90 000	96 000	99 000	96 000	97 400	99 500
11	71 331	82 552	76 118	87 183	79 548	91 674	96 565	88 779	95 377	98 812	95 507	97 220	99 374
12	67 800	80 126	73 385	85 373	77 229	90 309	96 147	87 672	94 765	98 618	95 130	97 040	99 236
13	64 402	77 724	70 793	83 572	75 036	88 907	95 747	86 676	94 165	98 418	94 753	96 860	99 086
14	61 137	75 348	68 334	81 781	72 962	87 470	95 365	85 786	93 577	98 212	94 377	96 680	98 924
15	58 000	73 000	66 000	80 000	71 000	86 000	95 000	85 000	93 000	98 000	94 000	96 500	98 750

Sample customised CP life tables applicable in California – q_x from age 4 to 14

q_x	Cannot lift head		Lifts head or chest		Partial rolling			Full rolling			Walks unaided		
	Tube fed	FOBO	Tube fed	FOBO	Tube fed	FOBO	Self fed	Tube fed	FOBO	Self fed	Tube fed	FOBO	Self fed
4	4.53%	2.52%	4.00%	1.84%	3.44%	1.04%	0.55%	2.01%	0.70%	0.15%	0.80%	0.55%	0.05%
5	4.59%	2.58%	3.94%	1.87%	3.37%	1.11%	0.53%	1.90%	0.69%	0.16%	0.75%	0.51%	0.07%
6	4.65%	2.64%	3.88%	1.91%	3.29%	1.17%	0.51%	1.80%	0.68%	0.16%	0.70%	0.46%	0.08%
7	4.71%	2.70%	3.82%	1.94%	3.22%	1.23%	0.50%	1.69%	0.67%	0.17%	0.65%	0.42%	0.09%
8	4.77%	2.76%	3.77%	1.97%	3.14%	1.30%	0.48%	1.58%	0.67%	0.18%	0.61%	0.37%	0.10%
9	4.83%	2.82%	3.71%	2.01%	3.07%	1.36%	0.47%	1.47%	0.66%	0.18%	0.56%	0.32%	0.11%
10	4.89%	2.88%	3.65%	2.04%	2.99%	1.43%	0.45%	1.36%	0.65%	0.19%	0.51%	0.18%	0.13%
11	4.95%	2.94%	3.59%	2.08%	2.92%	1.49%	0.43%	1.25%	0.64%	0.20%	0.39%	0.19%	0.14%
12	5.01%	3.00%	3.53%	2.11%	2.84%	1.55%	0.42%	1.14%	0.63%	0.20%	0.40%	0.19%	0.15%
13	5.07%	3.06%	3.47%	2.14%	2.76%	1.62%	0.40%	1.03%	0.62%	0.21%	0.40%	0.19%	0.16%
14	5.13%	3.12%	3.42%	2.18%	2.69%	1.68%	0.38%	0.92%	0.62%	0.22%	0.40%	0.19%	0.18%

Statistics from above table for ages 4 to 15 for comparison to Californian study:

	t^P_4	
	6	11
Cannot lift head		
Tube fed	75%	58%
FOBO	85%	73%
Lifts head not chest		
Tube fed	79%	66%
FOBO	89%	80%
Partial rolling		
Tube fed	82%	71%
FOBO	93%	86%
Self fed	97%	95%
Full rolling		
Tube fed	90%	85%
FOBO	96%	93%
Self fed	99%	98%
Walks unaided		
Tube fed	96%	94%
FOBO	97%	97%
Self fed	100%	99%

The statistics align to the Californian study Table 2 (adjusted to 2010 figures) for all categories and time periods.

APPENDIX C

Shape of life tables – adjusted standard vs customised from age 15



