

DEATH'S DOMINION

How fast does the Grim Reaper walk?

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Objective To determine the speed at which the Grim Reaper (or Death) walks.

Design Population based prospective study.

Setting Older community dwelling men living in Sydney, Australia.

Participants 1705 men aged 70 or more participating in CHAMP (Concord Health and Ageing in Men Project).

Main outcome measures Walking speed (m/s) and mortality.

Receiver operating characteristics curve analysis was used to calculate the area under the curve for walking speed and determine the walking speed of the Grim Reaper. The optimal walking speed was estimated using the Youden index (sensitivity+specificity-1), a common summary measure of the receiver operating characteristics curve, and represents the maximum potential effectiveness of a marker.

Results The mean walking speed was 0.88 (range 0.15-1.60) m/s. The highest Youden index (0.293) was observed at a walking speed of 0.82 m/s (2 miles (about 3 km) per hour), corresponding to a sensitivity of 63% and a specificity of 70% for mortality.

Survival analysis showed that older men who walked faster than 0.82 m/s were 1.23 times less likely to die (95% confidence interval 1.10 to 1.37) than those who walked slower ($P=0.0003$). A sensitivity of 1.0 was obtained when a walking speed of 1.36 m/s (3 miles (about 5 km) per hour) or greater was used, indicating that no men with walking speeds of 1.36 m/s or greater had contact with Death.

Conclusion The Grim Reaper's preferred walking speed is 0.82 m/s (2 miles (about 3 km) per hour) under working conditions.

As none of the men in the study with walking speeds of 1.36 m/s (3 miles (about 5 km) per hour) or greater had contact with Death, this seems to be the Grim Reaper's most likely maximum speed; for those wishing to avoid their allotted fate, this would be the advised walking speed.

Introduction

The Grim Reaper, the personification of death, is a well known mythological and literary figure.¹⁻⁴ Reported characteristics include a black cloak with cowl, a scythe, and cachexia. High quality scientific research linking the Grim Reaper to mortality has been scarce, despite extensive anecdotes.

Walking speed is a commonly used objective measure of physical capability in older people, predicting survival in several cohort studies.⁵⁻⁷ A recent meta-analysis found that being in the lowest fourth of walking speed compared with the highest was associated with a threefold increased risk of mortality.⁸ Moreover, the association between slow walking speed and mortality seems consistent across several ethnic groups and shows a dose-response relation.⁸ Although the association between walking speed and mortality has been well documented, the plausible biological relation between the two remains unclear.

We assessed whether the relation between slow walking speed and mortality results from the increased likelihood of being caught by Death. By assessing this relation using receiver operating characteristics curve analysis, we hypothesised we would be able to determine the walking speed of the Grim Reaper—information of importance to public health.

Methods

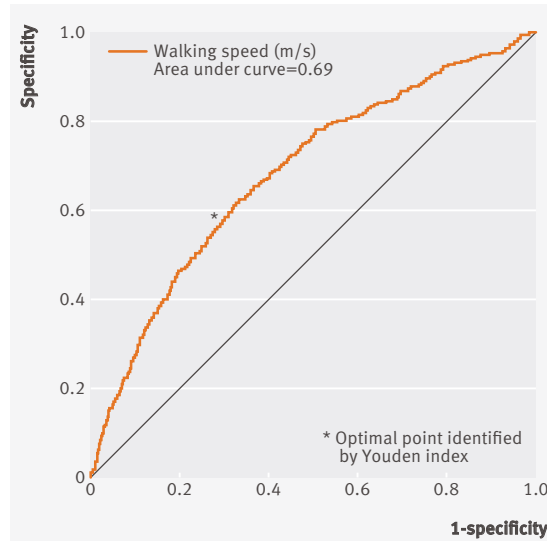
We analysed data from the Concord Health and Ageing in Men Project (CHAMP), a cohort study of men aged 70 and over living in several inner city suburbs of Sydney, Australia.⁹ Participants were recruited from the electoral roll, which, as voting is compulsory in Australia, provides a representative population sample. As "living" in the study area was a criterion for entry to the study, we were unable to obtain Death's participation in clinic assessments. In addition, as far as we are aware Death is currently not listed on the Australian electoral roll.

Men were recruited from January 2005 to June 2007 and baseline assessments carried out at the first clinic visit. The only exclusion criterion was living in an aged care facility.

Walking speed was measured at usual pace.^{10 11} Trained



Receiver operating characteristics curve for mortality over five years in relation to walking speed. *Optimal point identified by Youden index



staff used a stopwatch to record the time taken by the men to walk 6 m. The fastest time from two trials was used. Walking speeds were adjusted for height based on the definition of frailty used in the Cardiovascular Health Study.¹¹

The men were followed-up by telephone at four-monthly intervals from the baseline assessment, and at clinic visits at two and five years, which enabled survival data to be updated. For both the baseline and follow-up visits, the men completed a questionnaire at home before coming to the clinic at Concord Hospital. Men who were not contactable by phone were sent letters every four months, or if unavailable a nominated contact was telephoned. If men withdrew from the study but agreed to passive follow-up, we ascertained any deaths through the New South Wales registry of births, deaths, and marriages. Follow-up times varied between men (mean 59.3 months). Follow-up began at the baseline assessment and ended on the date of death or the end of the study period. For withdrawals, the end date was the date at which we contacted the death registry.

Statistical analyses

Analysis was done using SAS version 9.2. We used receiver operating characteristics curve analysis (Sigmaplot program, version 11.0, Systat Software) to calculate the area under the curve for walking speed and to determine the optimal cut-off value for avoiding contact with Death. On the basis of our hypothesis, we took this optimal cut-off for walking speed to be the best estimation of the Grim Reaper's pace. The area under the curve describes the test's overall performance and can be used to compare different tests. A value of 1 indicates perfect discrimination, whereas a value of 0.5 indicates discrimination no better than chance.

We also calculated sensitivity and specificity. The optimal cut-off point was obtained by using the Youden index (sensitivity+specificity-1), without adjusting for covariates. This index represents the maximum potential effectiveness of a marker.¹² Statistical significance was set at less than 0.05. We also estimated the walking speed providing a sensitivity of 1.0 (a "negative" test result being a speed above the cut-off) as this cut-off would indicate the speed at which no men had contact with Death and therefore the maximum ambulatory speed of the Grim Reaper. This maximum speed might be used

in particular instances where people are attempting to outrun Death and avoid their allotted fate. Cox regression analysis was also carried out to estimate the hazard ratio (95% confidence intervals) for mortality for men with walking speeds above and below that estimated for the Grim Reaper. The walking speed was also tested as a continuous variable.

Results

Of 2815 eligible men contacted, 1511 (53.7%) participated in the study. An additional 194 men living in the study area heard about the study (from friends or the local media) and were recruited before receiving an invitation letter, giving a final sample of 1705. As the CHAMP study area has a high proportion of immigrants, only 49.8% of men in the CHAMP study were born in Australia and 19.6% in Italy. Other main countries of birth were Great Britain (4.6%), Greece (3.9%), and China (2.7%). The men have been followed for a mean of 59.3 months. Walking speed at baseline was not available in 77 men, mostly through inability to complete the test. A total of 266 deaths occurred during follow-up.

The mean walking speed was 0.88 (range 0.15-1.60) m/s. The figure shows the receiver operating characteristics analysis. The highest Youden index (0.293) was observed at a walking speed of 0.82 m/s (2 miles (about 3 km) per hour), which corresponded to a sensitivity of 63% and a specificity of 70%. Cox regression analysis showed that older men with a walking speed above 0.82 m/s were 1.23 times less likely to die (95% confidence interval 1.10 to 1.37) than those who had a slower walking speed ($P=0.0003$). For every one unit (m/s) increase in walking speed, the hazard ratio for increased mortality was 2.77 (95% confidence interval 2.08 to 3.68; $P<0.001$). Moreover, a sensitivity of 1.0 was obtained when a walking speed of 1.36 m/s (3 miles (about 5 km) per hour) or greater was used, indicating that no men with walking speeds of 1.36 m/s or greater had contact with Death.

Discussion

Based on receiver operating characteristics analysis and estimation of the Youden index, a walking speed of 0.82 m/s (2 miles (about 3 km) per hour) was most predictive of mortality. Therefore, we predict that this is the likely speed at which the Grim Reaper prefers to ambulate under working conditions. Older men who walked at speeds greater than 0.82 m/s were 1.23 times less likely to encounter Death. In addition, no men walking at speeds of 1.36 m/s (3 miles (about 5 km) per hour) or above were caught by Death ($n=22$, 1.4%).

This supports our hypothesis that faster speeds are protective against mortality because fast walkers can maintain a safe distance from the Grim Reaper. Interestingly, the predicted walking speed of Death estimated in the present study is virtually identical to the gait speed (0.80 m/s) associated with median life expectancy at most ages and for both sexes in a recent meta-analysis of gait speed and mortality using data from diverse populations.⁸ This indicates that the preferred walking speed of the Grim Reaper while collecting souls is relatively constant irrespective of people's geographical location, sex, or ethnic background.

References are in the version on bmj.com

Response on bmj.com

"This raises the research question—does the Grim Reaper prefer to walk on level surfaces? Researchers who are able to access data directly from the Grim Reaper may like to pursue this line of investigation." Anne-Marie Hill, Freemantle Australia
 Join the online debate by clicking "Respond to this article"

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