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Differences in physical aging measured by walking speed

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Contents

Abstract

Background: Physical functioning and mobility of older populations are of increasing interest when populations are aging. Lower body functioning such as walking is a fundamental part of many actions in daily life. Limitations in mobility threaten independent living as well as quality of life in old age. In this study we examine differences in physical aging and convert those differences into the everyday measure of single years of age.

Methods: We use the English Longitudinal Study of Ageing, which was collected biennially between 2002 and 2012. Data on physical performance, health as well as information on economics and demographics of participants aged 50 years and above were collected over a ten years period. Lower body performance was assessed with two timed walks at normal pace each of 8 ft (2.4 m) of survey participants aged at least 60. We employed latent growth models to study differences in physical aging and followed the characteristic based age approach to illustrate those differences in single years of age.

Results: First, we examined walking speed of about 11,700 Englishmen, whereat we identified differences in age trajectories by sex and characteristics (e.g. education, occupation, regional wealth). Interestingly, higher educated and non-manual workers outperformed their counterparts for both men and women. Moreover, we transformed the differences between subpopulations into single years of age to demonstrate the magnitude of those gaps, which appear very high at early older ages particularly.

Conclusions: This paper expands research on aging and physical performance. In conclusion, higher education provides an advantage of up to 15 years for men and 10 years for women. Thus, encouragements in higher education have the potential to ensure better mobility and independent living in old age for a longer period.

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1 Introduction

Looking at functional capacities such as physical and cognitive function, the aging process varies across populations and across populational subgroups (Soer et al. 2012; Leopold & Engelhardt 2013; Sanderson & Scherbov 2014; Weber et al. 2014). Walking is one of those physical capacities, which represents musculoskeletal strength and power. It is required for any dynamic activity and hence ensures independent life at higher ages. There are several dimensions of walking such as gait rate, stride length, and walking speed (also termed gait speed). The measure walking speed is very popular in aging surveys as it can easily be assessed by nonprofessional staff.

Some previous research showed that walking speed declines with age, whereas men outperform women at all ages. In a meta analysis researchers identified walking speed to be relatively consistent between the age decades up to late 60s in both sexes, thereafter the mean pace was significantly less than in the previous decade (Bohannon & Andrews 2011).

Moreover, walking speed is associated with survival at all ages in both sexes, and particularly informative for people aged 75 years and higher (Studenski et al. 2011; Cooper et al. 2014). Over and above survival, objective physical capability measures such as walking speed are also predictors of general health in elderly (Cooper et al. 2014). Factors explaining this association are manifold such as health behavior, cardiovascular risk factors, and even more important inflammatory markers (Elbaz et al. 2013).

The aims of this study are to investigate the differences in physical aging, proxied with mean walking speed, between subpopulations of England’s older adults and to convert those differences into a more common measure.

2 Data

We used the English Longitudinal Study of Ageing (ELSA), which is a longitudinal study of a representative sample of the English non-institutionalized population aged 50 years and older. The first wave was collected in 2002 and thereafter participants were reinterviewed every second year until 2012. Sample refreshment were added in waves three, four and six (Banks et al. 2014; Steptoe et al. 2013). Data were collected within a face-to-face interview using CAPI (computer- assisted personal interview) and a self-completion questionnaire. In addition, there was a nurse visit in waves two, four, and six to measure physical functioning and to take blood samples as well as anthropometric measurements.

For the present study we use all six available waves; thus panel data over a period of ten years.

Subjects. ELSA used a multistage, clustered, stratified sampling strategy to draw the sample. In total, about 17,980 participants were interviewed within all six waves. We restricted the data to participants aged between 60 and 89 years for this study. Further, we excluded people if their self-assessed age and the calculated age based on year of birth and survey year differed by more than two years. Only non-institutionalized older adults with complete data on walking speed were selected, whereas a speed of less than 0.09m/s was considered as missing. These restrictions resulted in a final sample of 5,490 men, 6,221 women (N=11,711) and in total 35,596 observations. Table 1 provides a descriptive overview for each wave.

Table 1. Descriptive sample overview by wave, including summary statistics such as mean (SD) on walking speed, age, height, and weight and shares of women, higher educated, non-manual worker, living in wealthier region.

variables	wave 1	wave 2	wave 3	wave 4	wave 5	wave 6
walking speed	0.85 (0.28)	0.85 (0.27)	0.84 (0.28)	0.86 (0.28)	0.88 (0.27)	0.88 (0.28)
age	70.6 (7.4)	70.6 (7.4)	70.5 (7.6)	70.0 (7.6)	70.1 (7.5)	70.1 (7.4)
height	1.64 (0.09)	1.64 (0.10)	1.65 (0.09)	1.65 (0.09)	1.66 (0.09)	1.65 (0.10)
weight	74.5 (14.1)	75.1 (14.7)	75.9 (14.8)	76.8 (15.4)	77.8 (15.5)	77.6 (15.9)
females	54.47	54.85	53.94	53.57	52.72	52.97
higher educated	38.57	42.43	51.33	52.63	57.43	60.9
non-manual occupation	50.33	51.89	52.09	53.09	55.29	57.47
wealthier region	50.06	49.86	50.58	52.24	51.98	51.63
unweighted N	6107	5458	5181	6213	6330	6347

3 Measures

Walking speed. Each participant aged 60 and above was eligible for the *timed walk* test. In addition, prior to the actual test respondents were asked if they had any problems from recent surgery, injury, or other health conditions that might prevent them from walking. Only persons aged at least 60 years, willing to do the test and being able to walk (walking aids were permitted) were asked to walk twice 8 feet (2.4m) at their usual walking pace. The time for both walks was recorded separately. In our analysis we use the mean speed (measured in m/s) of the two trials.

Anthropometrics. The anthropometric measures body weight and height were taken by nurses in waves two, four, and six. A body weight of less than 29kg and a body height of less than 1.29m were coded as missing information. In our analysis we included the mean height and weight of each participant to overcome the information lack in the odd waves.

Education. Information about the highest educational qualification was collected within the first interview. Thereafter (e.g. in the follow-up interviews) all participants were asked whether further education was attended and if so which one. Participants could select one out of seven categories ranging between no qualification and higher education with degree. We coded the seven categories into higher educated (nvq2/gce or higher) and lower educated (no qualification or nvq1/cse).

Occupation. Current or most recent job information was provided for each respondent using the National Statistics socio-economic classification (NS-SEC). We dichotomized that variable by clustering managerial, professional, and intermediate occupations into non-manual occupation and routine and manual occupations into manual occupation.

Regional wealth. The Government Office Region (GOR) variable was available for each participant. We categorized North East, North West, Yorkshire and The Humber, East Midlands, and West Midlands as less wealthier region and East of England, London, South East, and South West as wealthier region, whereas a Regional Gross Value Added (GVA) per head of less than £21,000 per capita in 2013 was used as cutoff point (Office for National Statistics 2014).

4 Methods

Following a sample description, we identified differences in walking speed. We explored these differences in physical function by age and subpopulations with growth curve models (Raudenbush & Bryk 2002; Steele 2008). The subpopulations were distinguished by three different characteristics (i.e. regional wealth and the two socio- economic classification characteristics education and occupation). The models were applied separately by sex and characteristics.

First, we identified a non-linear growth model considering mean weight, mean height and survey wave as covariates (verified by likelihood-ratio tests). We added the dummy coded group variable for the subpopulation with less education, manual occupation, and living in a less wealthy region as reference categories for examining between-person variability in walking speed. In addition, we included an acceleration subpopulation effect for women and a slope subpopulation effect for men (identified by likelihood-ratio tests). Further, the time variable age was centered at 70 years, the mean age within our data sample.

The model for women was specified as follows:

$$Y_{ti} = \pi_{0i} + \pi_{1i}(age_{ti} - 70) + \pi_{2i}(age_{ti} - 70)^2 + \pi_{3i}wave_{ti} + e_{ti}$$

$$\pi_{0i} = \beta_{00} + \beta_{01}group_i + \beta_{02}height_i + \beta_{03}weight_i + r_{0i}$$

$$\pi_{1i} = \beta_{10} + r_{1i} \quad \pi_{2i} = \beta_{20} + \beta_{21}group_i$$

$$\pi_{3i} = \beta_{30}$$

and for men:

$$Y_{ti} = \pi_{0i} + \pi_{1i}(age_{ti} - 70) + \pi_{2i}(age_{ti} - 70)^2 + \pi_{3i}wave_{ti} + e_{ti}$$

$$\pi_{0i} = \beta_{00} + \beta_{01}group_i + \beta_{02}height_i + \beta_{03}weight_i + r_{0i}$$

$$\pi_{1i} = \beta_{10} + \beta_{11}group_i + r_{1i} \quad \pi_{2i} = \beta_{20}$$

$$\pi_{3i} = \beta_{30}$$

with *i* indicating the individual and *t* indicating the wave. We assumed that the errors e_{ti} were independent and normally distributed with common variance σ^2.

Finally, the magnitudes of the variability due to education, occupation or regional wealth were converted into single years of age following a characteristic-based age approach (Ryder 1975; Sanderson & Scherbov 2013). In more detail, walking speed was written as a function of chronological age and a set of covariates for each sex. These functions were used to calculate the so called α-ages $\alpha_{k,t}$, whereat $\alpha_{k,t}$ represents the chronological age of the "higher" subpopulation equivalent to a particular walking speed *k* at age *t* of the reference subpopulation (Sanderson and Scherbov 2013). Thus to highlight the differences in physical aging, we can report the α-ages for higher educated, non-manual workers, and people living in wealthier regions associated with the walking speed of their counterparts at a certain age.

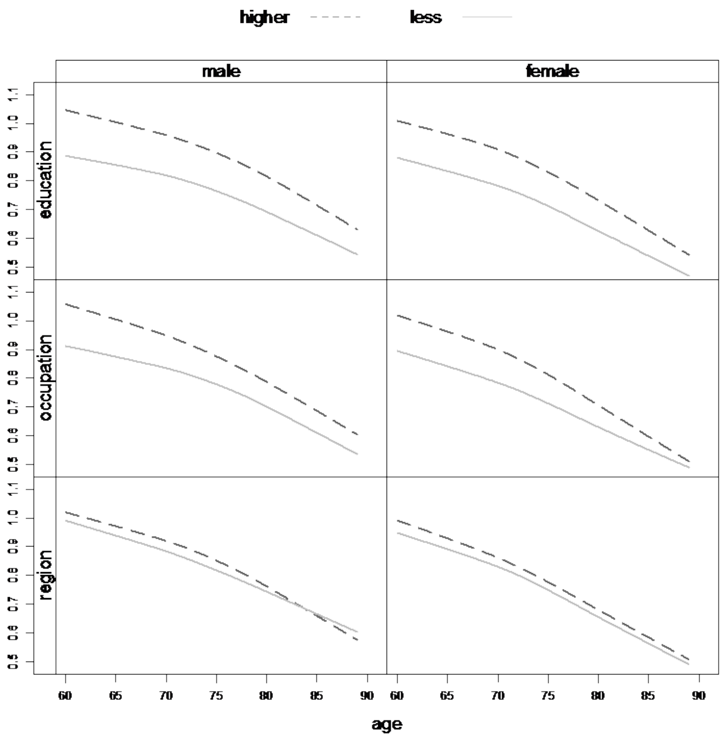
We carried out all analyses and produced all figures with R 3.0.2 (R Core Team 2013). Sampling weights were used for all descriptive statistics to adjust for non-response and to ensure population representativeness.

5 Results

In total our selected sample included 11,711 people who participated at least in one of the six waves of ELSA. About 12.7 % of the participants aged at least 60 had to be excluded, as they did not participate in the timed walking test. An overview of our sample including descriptive statistics by survey wave is presented in Table 1.

As previously reported, men showed faster walking speed over all ages than women. Moreover, differences were not only observed across sex, but also observed across subpopulations demonstrating a socio-economic gradient that indicated an advantage of higher socio-economic class subpopulations for both sexes. Additionally, the analysis of the pooled six waves enabled us to confirm a non-linear age effect on walking speed.

Figure 1. Trajectories of walking speed across subpopulations: average walking speed by age and subpopulation separately by sex and characteristics (education, occupation, and regional wealth).



Focusing first on differences in lower body performance due to education, higher educated men and women walked on average faster than their lower educated counterparts. This was particularly true for the population aged about 60 years of both sexes (see Figure 1). However, age and education interactions varied by gender. The interaction between age^2 and education was significant for women, but there was no significant interaction between age and education for men (Tables A1a and A1b). The advantage of higher educated women diminished slightly at higher ages.

In occupational subgroups, non-manual workers walked on average faster than manual workers (see Figure 1). Interestingly, the gap in walking speed between the occupational subpopulations almost vanished at higher ages, particularly for women. In contrast to education, occupational subpopulations experienced significantly different aging in walking speed for both gender indicating a flatten advantage of non-manual workers (Tables A2a and A2b).

Turning to the region of living, there was a tendency of a slightly higher walking speed for people living in wealthier regions. However, this gap almost vanished particularly for women. There was also no significant interaction between age and regional wealth for neither women nor men (Tables A3a and A3b).

To emphasize the extent to which our investigated characteristics education, occupation, and regional wealth contributed to differences in physical aging, α-ages were calculated for subpopulations separately by gender. For instance, lower educated women aged 60 years performed at the same walking speed as their almost 10 years older higher educated counterparts. A higher occupational status was associated with an advantage of 9 years for 60 years old women, whereas higher regional wealth provided an advantage of only four years. These advantages diminished to only two and one years at older age (Table 2).

Table 2. Alpha-ages of higher educated women, women with higher occupation status, and women living in wealthier regions.

age	α-ages education	α-ages occupation	α-ages region
60	70.82	69.18	64.05
65	73.37	72.39	67.83
70	76.52	75.89	72.14
75	80.03	79.58	76.72
80	83.75	83.37	81.43
85	87.61	87.23	86.22

Turning to men, we found even bigger gaps between subpopulations. For instance, a 60 year old lower educated man walked on average at the same pace as his 15 years older higher educated counterpart, whereas at higher ages the gap shrank to a five years advantage. In occupational subpopulations, the difference ranged from 13 years at younger ages to 2.7 years at higher ages. For regional wealth, the results were similar to women's showing a four years advantage at younger ages and a difference of one year at higher ages (Table 3).

Table 3. Alpha-ages of higher educated men, men with higher occupation status, and men living in wealthier regions.

age	α-ages education	α-ages occupation	α-ages region
60	75.38	73.05	64.44
65	76.73	74.36	67.75
70	79.17	76.77	71.94
75	82.4	79.96	76.48
80	86.13	83.67	81.2
85	90.21	87.72	86.0

6 Discussion

In this study we explored the non-linear age trajectory of walking speed as a proxy of lower body functioning of England's older adults using six waves of ELSA. The mean walking speed declined by age for both sexes with men performing at higher levels than their female counterparts. Next to the variation across age and sex we moreover detected disparities between subpopulations distinguished by either socio-economic factors or regional wealth.

Earlier reports highlighted the importance of the lower extremity function walking, which was predictive of institutionalization, hospitalization, and mortality in particular at older age (Studenski et al. 2011; Elbaz et al. 2013; Blain et al. 2010; Guralnik et al. 1994). Moreover, a loss of mobility represents a turning point in older person's life as it was linked with the slowing down process (Himann et al. 1988; Ferrucci & Guralnik 2013). Previous research showed that the age decline for normal walking speed started at the 60s only and that a speed of less than 0.6m/s is analog to substantial impairments (Bohannon & Andrews 2011; Ferrucci & Guralnik 2013; Bohannon 1997). Therefore, older adults in particular should aim for sustaining walking speed at a high level.

We found that higher education was associated with higher walking speed for both sexes and across all ages. A 70 years old higher educated person walked with an about 0.1m/s faster normal pace than the lower educated counterpart considering covariates. This was in accordance with previous studies (Welmer et al. 2013; Zaninotto et al. 2013). For instance, in a cross-sectional study on advanced aged Swedish higher education was associated with better lower extremity performance, such as walking speed, balance, chair stands, and in addition with upper extremity performance hand grip strength (Welmer et al. 2013).

Interestingly, Studenski et al. (2011) reported an increase of 0.1m/s in gait speed to be associated with 0.88 survival hazard. An added value of our study is the conversion into α-ages, which highlights the advantage in single years. Roughly speaking, high educated 70 years old can be associated with a 0.88 survival hazard. In other words, lower educated 70 years old walked on average at the same pace as 6.5 to 9 years older counterparts. However, our findings suggest a faster acceleration of the age decline among higher educated women, but no significant interaction between education and age among men.

When looking at disparities in walking speed due to occupation, another dimension of socio- economic status, we received similar results. Older adults with higher occupational status per- formed at higher levels within the walking speed test than manual workers for both sexes across all ages. The advantage in walking speed due to higher occupational status was slightly less than the one due to higher education, which could be best emphasized with α-ages. It strikes that there is a significant age occupational status interaction for both sexes, although we did not find a significant education age interaction for men.

Numerous studies documented, that in particular at older ages higher socioeconomic status was positively associated with better physical functioning such as upper extremity functions hand (e.g. grip strength) as well as lower extremity functions (e.g. walking speed, chair stand, and balance), but also with less impairments such as the Instrumental Activities of Daily Living (IADL) (Welmer et al. 2013; Ostir et al. 2007; Zaninotto et al. 2013; Sanderson & Scherbov 2014). However, these studies were inconsistent when it came to the significance of the interaction between socioeconomic status and age, which we could confirm by investigating separately the effect of education and occupation.

Next to individual factors, we also found that living in a wealthier region was positively assigned with higher walking speed. This was in accordance with previous studies showing a positive association between regional factors (e.g. GDP, unemployment rate, regional development) and well-being, as well as higher cognitive performance (Gerstorf et al. 2010; Weber et al. 2014). However, the magnitude of the gap due to regional living was only minor in comparison to socioeconomic status (i.e 0.03m/s for men and 0.025m/s for women). Interestingly, the daily routine of walking for transportation instead of using the car might support the regional effect. A recent study by Van Cauwenberg et al. (2012) showed that older adults living in urban areas were more likely to walk daily for transportation than their counterparts living in semi-urban or rural areas. Moreover, feelings of unsafety were assigned to lower rates of walking for transportation.

Our analysis contributes to the literature on physical aging because next to confirming the socioeconomic and regional wealth differences in physical functioning it, moreover, highlights the differences with converting them into single years of age. Therefore, identifying socioeconomic differences in walking speed of up to 10 age years stresses the need of policy changes to address socioeconomic inequality. Our research and previous studies showed, that increasing socio-economic equality could contribute to better physical functioning, which is critical to the quality of older adults' daily lives.

7 Conclusion

In summary, this study identified disparities in lower body functioning between socioeconomic groups, whereas the magnitude of the difference in physical aging between sub-populations at older ages declined by age. Nevertheless, higher socioeconomic status such as higher education provided older adults an advantage in mobility of up to 15 years. Therefore, improving the living conditions and education of the disadvantaged groups may have a positive impact on lower body functioning in old age, which is positively assigned with independent living.

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9 Appendix

Table A1a. Linear Model of Growth in women's walking speed: effects of education.

Fixed Effect		Estimate	Std. Error	t value
Initial status				
	Intercept	-9.96E-02	8.10E-02	-1.229
	higher education	1.06E-01	7.36E-03	14.343
	pheight	7.77E-01	5.36E-02	14.485
	pweight	-4.62E-03	2.31E-04	-20.034
Aging growth rate				
	Intercept	-1.30E-02	4.29E-04	-30.314
Aging acceleration rate				
	Intercept	-3.55E-04	4.65E-05	-7.619
	higher education	-1.34E-04	6.69E-05	-1.998
Wave growth rate				
	wave 2	8.69E-04	4.75E-03	0.183
	wave 3	-1.33E-02	5.04E-03	-2.639
	wave 4	-1.64E-02	5.20E-03	-3.155
	wave 5	-4.29E-03	5.55E-03	-0.773
	wave 6	-7.73E-03	5.89E-03	-1.312
Random Effect		Variance	Std. Dev.	
Level 1	Temporal variation	2.34E-02	0.15288	
Level 2	Ind. initial status	3.08E-02	0.175435	
	Ind. aging	6.75E-05	0.008214	
Observations:		15159		

Table A1b. Linear Model of Growth in men's walking speed: effects of education.

Fixed Effect		Estimate	Std. Error	t value
Initial status				
	Intercept	1.43E-01	9.08E-02	1.573
	higher education	1.31E-01	7.30E-03	17.882
	pheight	5.39E-01	5.75E-02	9.379
	pweight	-2.72E-03	2.75E-04	-9.878
Aging growth rate				
	Intercept	-1.04E-02	4.79E-04	-21.737
	higher education			
Aging acceleration rate		-4.16E-04	3.95E-05	-10.534
	Intercept			
Wave growth rate				
	wave 2	-6.31E-04	5.22E-03	-0.121
	wave 3	-1.84E-02	5.54E-03	-3.319
	wave 4	-2.24E-02	5.73E-03	-3.909
	wave 5	-1.04E-02	6.14E-03	-1.692
	wave 6	-1.27E-02	6.55E-03	-1.944
Random Effect		Variance	Std. Dev.	
Level 1	Temporal variation	2.47E-02	0.157138	
Level 2	Ind. initial status	3.24E-02	0.179967	
	Ind. aging	9.50E-05	0.009749	

Observations: 13643

Table A2a. Linear Model of Growth in women's walking speed: effects of occupation.

Fixed Effect		Estimate	Std. Error	t value
Initial status				
	Intercept	-7.45E-02	7.69E-02	-0.97
	higher occupation	9.92E-02	6.86E-03	14.4
	pheight	7.47E-01	5.09E-02	14.67
	pweight	-4.43E-03	2.23E-04	-19.89
Aging growth rate				
	Intercept	-1.41E-02	4.02E-04	-35.09
Aging acceleration rate				
	Intercept	-3.07E-04	4.93E-05	-6.22
	higher occupation	-1.54E-04	6.41E-05	-2.4
Wave growth rate				
	wave 2	4.48E-03	4.53E-03	0.99
	wave 3	-7.96E-03	4.80E-03	-1.66
	wave 4	-7.72E-03	4.95E-03	-1.56
	wave 5	6.54E-03	5.26E-03	1.24
	wave 6	6.96E-03	5.58E-03	1.25
Random Effect		Variance	Std. Dev.	
Level 1	Temporal variation	2.32E-02	0.152446	
Level 2	Ind. initial status	3.05E-02	0.174682	
	Ind. aging	7.17E-05	0.008467	
Observations:		16609		

Table A2b. Linear Model of Growth in men's walking speed: effects of occupation.

Fixed Effect		Estimate	Std. Error	t value
Initial status				
	Intercept	5.25E-02	8.89E-02	0.59
	higher occupation	1.05E-01	6.96E-03	15.141
	pheight	5.96E-01	5.62E-02	10.618
	pweight	-2.73E-03	2.69E-04	-10.129
Aging growth rate				
	Intercept	-1.05E-02	6.80E-04	-15.436
	higher occupation	-0.00222	0.000791	-2.807
Aging acceleration rate				
	Intercept	-4.22E-04	3.90E-05	-10.817
Wave growth rate				
	wave 2	1.16E-03	5.13E-03	0.227
	wave 3	-1.01E-02	5.43E-03	-1.868
	wave 4	-1.46E-02	5.61E-03	-2.612
	wave 5	1.22E-03	5.97E-03	0.204
	wave 6	1.74E-03	6.35E-03	0.273
Random Effect		Variance	Std. Dev.	
Level 1	Temporal variation	2.47E-02	0.157148	
Level 2	Ind. initial status	3.28E-02	0.180996	
	Ind. aging	9.67E-05	0.009833	
Observations:		14159		

Table A3a. Linear Model of Growth in women's walking speed: effects of regional wealth.

Fixed Effect		Estimate	Std. Error	t value
Initial status				
	Intercept	-1.82E-01	7.76E-02	-2.35
	wealthier region	3.23E-02	6.07E-03	5.32
	pheight	8.55E-01	5.11E-02	16.73
	pweight	-0.0048	0.000223	-21.5
Aging growth rate				
	Intercept	-0.0142	0.000403	-35.39
Aging acceleration rate				
	Intercept	-3.92E-04	3.27E-05	-12.01
	wealthier region			
Wave growth rate				
	wave 2	3.05E-03	4.48E-03	0.68
	wave 3	-8.02E-03	4.75E-03	-1.69
	wave 4	-8.28E-03	4.91E-03	-1.69
	wave 5	6.80E-03	5.23E-03	1.3
	wave 6	0.0082	0.00555	1.48
Random Effect		Variance	Std. Dev.	
Level 1	Temporal variation	2.33E-02	0.15251	
Level 2	Ind. initial status	0.0325	0.18024	
	Ind. aging	0.0000728	0.00853	
Observations:		16948		

Table A3b. Linear Model of Growth in men's walking speed: effects of regional wealth.

Fixed Effect		Estimate	Std. Error	t value
Initial status				
	Intercept	-7.43E-02	9.07E-02	-0.818
	wealthier region	2.50E-02	6.87E-03	3.642
	pheight	7.11E-01	5.71E-02	12.448
	pweight	-0.00299	0.000275	-10.881
Aging growth rate				
	Intercept	-0.0121	0.00047	-25.741
	wealthier region			
Aging acceleration rate				
	Intercept	-0.000415	0.0000392	-10.588
Wave growth rate				
	wave 2	2.32E-03	5.13E-03	0.453
	wave 3	-9.40E-03	5.43E-03	-1.729
	wave 4	-1.21E-02	5.63E-03	-2.15
	wave 5	4.06E-03	6.02E-03	0.674
	wave 6	0.00585	0.00641	0.913
Random Effect		Variance	Std. Dev.	
Level 1	Temporal variation	2.47E-02	0.15721	
Level 2	Ind. initial status	0.0351	0.18724	
	Ind. aging	0.000104	0.01019	
Observations:		14290		