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The hour-to-hour influence of weather conditions on walking and cycling among Dutch older adults

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Abstract

Background: physical activity (PA) is an important factor to promote healthy ageing. However, older adults are not physically active enough. Socio-ecological models suggest that weather conditions are determinants of PA and may bias relations between other environmental factors and PA. This may especially be the case for the most vulnerable and inactive older persons. Understanding the role of weather conditions is based on daily or seasonal variation in weather, but it can be improved by using hour-to-hour measured weather conditions.

Purpose: to study the hour-to-hour relationships between weather factors and objectively measured walking and cycling in a sample of Dutch older adults.

Methods: baseline data (2013) of a sub-sample of older adults (3,248 observations clustered in 43 adults) participating in The Neighborhood Walking in Rotterdam Older ADultS (NEW.ROADS) trial were used. Participants wore a GPS logger for 7 consecutive days. Hour-to-hour weather data (temperature, wind speed, rain and sun time) for the city of Rotterdam were retrieved from the Royal Netherlands Meteorological Institute. Multilevel linear regression models were fitted with minutes walked and minutes cycled as dependent variables and the weather variables as independent variables.

Results: the time older adults walked increased with higher temperature, higher wind speed and the absence of rain. The time cycled increased with higher temperature.

Conclusions: this study improves the evidence of weather factors as a determinant for walking and cycling in older adults. Studies on the relation between environmental factors and PA should consider adjustment for weather factors.

Introduction

Physical activity (PA) is an important factor to promote healthy ageing [1, 2]. It may prevent age-related declines in mobility, falls, chronic diseases and all-cause mortality [3]. Yet, many older adults do not meet PA guidelines [4]. Therefore, research has focused on identifying socio-ecological determinants of PA [5, 6]. In this research, weather conditions are thought to be a determinant of PA. Weather may bias the relation between environmental determinants and PA [7]. Hence, if weather factors are determinants of PA, studies should take weather into account to mitigate bias.

Previous studies found seasonal variation in PA levels. [8] Seasonal variation in PA is often attributed to weather differences. However, it is unclear whether weather is the real reason for this variation, because many factors may cause seasonal variations in PA (e.g. changes in mood, health and functioning, social support or events organised). Recent studies linked weather and PA measured on a daily basis and eliminated these seasonal confounders. These studies found that weather factors influence PA among older adults [9, 10]. A limitation, however, is that persons can still be active in hours of a day in which the weather is better. Studies using weather and PA measured on an hour-to hour basis eliminate this potential confounder. As such, a study investigating the hour-to hour relation between weather and PA provides the best evidence for weather as a determinant of PA.

No previous studies that we are aware of used hourly weather conditions in relation to active travel among older adults, nor whether the importance of weather differed between types of active travel and for demographic subgroups. Therefore, we studied weather influences on walking and cycling on an hour-to-hour basis. Because weather is a larger barrier for groups that are generally less active and more vulnerable [11], we expect a larger impact of weather conditions on less active subgroups (i.e. women [12, 13], older [12, 13] and frail persons [13, 14]).

Methods

The NEighbourhood Walking in Rotterdam Older ADultS (NEW.ROADS) study aimed to evaluate the effect of social and physical environmental changes on walking in older adults (≥55 years). Between February and April 2013, 2,766 community-dwelling older adults living in Rotterdam (the Netherlands) were invited to participate in this study. This was done by sending an announcement and 2 weeks

thereafter questionnaires and consent forms. After 3 to 4 weeks, non-responders received a reminder. Four hundred and forty-two (16%) older adults completed the baseline measurements. A sub-sample of 48 participants wore a GPS logger (QStarz BT-Q1000XT) for 7 days between March and April. This sub-sample was recruited by calling participants in order from a random ranked list. Five participants returned GPS loggers without data, leaving a sample of 43 participants. The sample of GPS wearers was significantly less likely to be frail than the total sample, but no differences were found by gender, age and self-reported PA.

All participants gave written informed consent. The Medical Ethical Committee of the Erasmus Medical Centre, Rotterdam, approved this study.

Walking and cycling

Participants wore the GPS logger during waking hours on their right hip and charged it overnight. GPS data were measured in 10 s epochs. We used the Personal Activity Location Measurement System [15, 16] to remove spurious GPS points and to determine walking and cycling based on speed. We defined walking as speeds between 1 and 10 km/h and cycling as speeds between 10 and 25 km/h [17]. The data were aggregated to derive at hourly measures of minutes walked and cycled.

Weather

Hourly averages of temperature (Celsius), wind speed (m/s), any rain during the hour (no/yes) and the time the sun was visible (0.1 h) for Rotterdam were retrieved from the Royal Netherlands Meteorological Institute [18].

Covariates

The covariates were gender, age, work status, frailty, part of the day (AM/PM) and type of day (week/weekend). Age was categorised as ≤65 (younger older adults) and >65 years (oldest older adults). Frailty was measured with the Tilburg Frailty Indicator; participants were categorised as frail if their frailty scores were five or higher [19].

Analyses

First, we ran pairwise correlations between the covariates, weather factors and outcomes. Then we checked for multicollinearity; no evidence was found for this. Therefore, minutes walked and cycled were regressed on the weather variables and covariates in multivariate, multilevel linear regression models (with observations nested within

individuals). Subsequently, we added interaction terms between gender, age, frailty, work status and the weather factors. The significant interactions were stratified to interpret the significant interaction terms. All analyses were restricted to daylight hours (07:00–19:00) and were performed in Stata 13.0. Results were considered to be statistically significant at $P < 0.05$.

Results

Of the sample, 47.5% was male, 62.5% was older than 65 years, 47.5% was frail and 20% was (self-)employed (Table 1). On average, participants walked 5.26 (SD: 9.50) min/h and cycled 1.77 (SD: 4.73) min/h. Higher temperatures, the absence of rain and higher wind speeds were univariately and multivariately associated with more walking

(Tables 1 and 2). A higher temperature was associated with more cycling (Tables 1 and 2).

Interactions

Four interactions were statistically significant. The positive relation between temperature and cycling was stronger for frail ($b = 0.11$; $P = 0.002$) than for non-frail ($b = 0.04$; $P = 0.167$) persons. Furthermore, non-frail older adults cycled more when the average wind speed was higher ($b = 0.08$; $P = 0.031$), whereas frail older adults cycled less with increasing wind speed ($b = -0.10$; $P = 0.074$). Women tended to cycle less when there was rain ($b = -0.68$; $P = 0.136$), whereas men cycled more when there was rain ($b = 0.72$; $P = 0.027$). Younger older adults cycled less when there was more sunshine ($b = -0.58$; $P = 0.100$), whereas the oldest

Table 1. Pairwise correlations between walking, cycling, weather factors and covariates (3,248 observations clustered within 43 individuals)

		%/mean(SD)	1	2	3	4	5	6	7	8	9	10	11
1	Time walked	5.26 (9.50)	1.00										
2	Time cycled	1.77 (4.73)	0.10***	1.00									
3	Temperature	5.9 (5.0)	0.05**	0.13***	1.00								
4	Rain	9.4%	−0.04**	0.01	0.03	1.00							
5	Wind speed	6.0 (2.7)	0.05**	−0.01	−0.22***	−0.14***	1.00						
6	Sun hours	0.4 (0.4)	0.03	0.00	0.17***	−0.27***	0.11***	1.00					
7	Gender (% male)	47.5%	0.12***	−0.06***	−0.10***	0.01	0.03*	−0.00	1.00				
8	Age (% >65 years)	62.5%	0.01	0.02	0.05**	0.03	−0.04*	−0.02	−0.19***	1.00			
9	Frail	47.5%	0.01	0.08***	0.08***	−0.00	−0.00	0.02	−0.21***	−0.14***	1.00		
10	(Self-)employed (% yes)	20.0%	−0.08***	−0.01	−0.09***	−0.04*	0.11***	0.01	−0.00	−0.52***	0.03	1.00	
11	AM/PM		0.11***	0.09***	0.25***	0.04*	0.07***	0.01	−0.00	−0.00	0.00	0.00	1.00
12	Week/weekend		0.02	−0.04*	−0.19***	0.17***	0.12***	−0.30***	−0.00	−0.01	−0.01	0.00	−0.00

SD, standard deviation.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

Table 2. Results of linear multilevel regression analyses of hourly weather influences on time walked and time cycled

	Time walked		Time cycled	
	Unstandardised β (95% CI)	Standardised β (95% CI)	Unstandardised β (95% CI)	Standardised β (95% CI)
Covariates				
Gender—female	**2.58 (0.85; 4.31)**	**0.15 (0.05; 0.26)**	−0.45 (−1.19; 0.29)	−0.06 (−0.15; 0.04)
Age—percentage >65 years	0.33 (−1.77; 2.41)	0.02 (−0.10; 0.14)	0.12 (−0.77; 1.01)	0.01 (−0.09; 0.12)
Frail	0.54 (−1.16; 2.24)	0.03 (−0.07; 0.14)	0.53 (−0.19; 1.26)	0.07 (−0.02; 0.16)
(Self-)employed	−1.92 (−4.38; 0.54)	−0.09 (−0.21; 0.03)	−0.02 (−1.06; 1.03)	−0.00 (−0.11; 0.10)
Weather factors				
Temperature (Celsius)	**0.10 (0.01; 0.20)**	**0.06 (0.00; 0.12)**	**0.07 (0.02; 0.11)**	**0.09 (0.03; 0.15)**
Rain (no/yes)	**−2.09 (−3.21;−0.97)**	**−0.08 (−0.12;−0.04)**	−0.02 (−0.56; 0.53)	−0.00 (−0.04; 0.04)
Wind speed (m/s)	**0.14 (0.01; 0.27)**	**0.05 (0.00; 0.09)**	0.00 (−0.06; 0.07)	0.00 (−0.04; 0.05)
Sun hours (h)	0.40 (−0.45; 1.26)	0.02 (−0.02; 0.05)	−0.23 (−0.64; 0.19)	−0.02 (−0.06; 0.02)
Explained variance	Overall R^2		Overall R^2	
Covariates only	0.036		0.019	
Covariates + weather factors	0.043		0.028	

Bold values represent statistically significant associations; analyses were adjusted for part of the day (AM versus PM) and weekend or weekday.
CI, confidence interval; m/s, meters per second.

older adults cycled more with increasing sunshine ($b = 0.01$; $P = 0.956$). No interactions were found for walking.

Discussion

We found that hour-to-hour measured higher temperatures, higher wind speeds and the absence of rain were related to more walking in that hour. Hourly levels of cycling increased with higher temperatures. Most of the results did not differ according to demographic factors. However, for cycling, frailty interacted with temperature and wind speed, gender interacted with rain and age interacted with sunshine.

Previous studies have also found that older adults walked more with higher temperatures [9, 20–22] and the absence of rain [9, 20–22]. Contrary to other studies [9, 21], we found a positive instead of a negative association of wind speed with walking. Stronger winds did not affect the decision to walk or not (Supplementary data, Appendix A, available in *Age and Ageing* online). Hence, it may be that stronger winds increase the time a trip takes. In contrast to other studies [9, 10], we did not find an association between sunlight and walking. These studies used daily hours of sunlight, which may reflect 'daylight'. Whereas daylight may increase feelings of safety, hour-to hour sunlight may inhibit older adults to go outside [11].

Weather influences were largely independent of demographic factors, but some differences for minutes cycled were observed. Temperature had a stronger positive effect on minutes cycled among frail than non-frail older adults, confirming that weather influences vulnerable people more [11]. This is further confirmed with regard to wind speed. Higher wind speeds decreased the time cycled for frail older adults, whereas it increased among non-frail older adults. To explain this, we looked at the hourly odds of cycling in additional analyses. The hourly odds of cycling were negatively associated for frail participants; no association was found for non-frail participants (Supplementary data, Appendix A, available in *Age and Ageing* online). Apparently, non-frail older adults were less inhibited to cycle with higher wind speeds than non-frail older adults, but trips may take longer due to stronger winds.

Rain was positively associated with minutes cycled among men and negatively among women. This difference was also found for the odds of cycling (Supplementary data, Appendix A, available in *Age and Ageing* online). This is in line with a study in adults showing that rain is a more important barrier to cycle for women than for men [23]. Sunshine and age group also interacted; younger older adults cycled less with more sunshine and the oldest older adults cycled slightly more with more sunshine. This may reflect more a habitual behavioural pattern than a weather influence. The oldest older adults cycled significantly less in weekends than on week days (data not shown), and on weekend days, there was significantly less sunshine than in weekdays.

A major strength of this study is the use of objectively measured observations of walking and cycling and the use of local hour-to-hour weather data. A limitation of this study is that we measured behaviour in one season. More seasonal variation is likely to strengthen our results. Another limitation is that although the derivation of walking and cycling using the speed was based on previous research [17], the cut-off points were not validated in older adults. It may thus be that other activities were performed than the activities we classified. For instance, it may be that some older adults cycled slowly, which may be categorised as walking. With regard to generalisability of our findings, the sub-sample that wore the GPS loggers was less likely to be frail than the total sample. Therefore, our results are probably conservative, as vulnerable people are more likely to experience influence of weather on their PA [11].

This study shows that weather conditions are important to consider when assessing PA in older adults. Weather factors may bias associations between environmental factors and PA, when PA is assessed on an hour-to-hour basis. Thus, weather is indeed likely to affect the potential impact of physical environmental interventions [24].

Key points

- Weather factors are related to walking and cycling behaviour of older adults.
- Weather factors are largely independent of the mode of travel (i.e. walking or cycling).
- Studies aimed at evaluating environmental interventions should consider adjustment for weather factors.

Conflicts of interest

None declared.

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Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

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