Pacing Patterns of Half-Marathon Runners: An analysis of ten years of results from Gothenburg Half Marathon

Moa Johansson, Johan Atterfors, Johan Lamm

Chalmers University of Technology
Department of Computer Science and Engineering
SE-412 96 Gothenburg
Sweden

Corresponding author:
Moa Johansson, moa.johansson@chalmers.se

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Abstract

Objectives

Every year over 40 000 runners complete Gothenburg Half Marathon, one of the world's largest half-marathons. As participation in recreational races become more common among e.g., older people and those without extensive training experience, providing advice on how to plan the pacing during race is valuable and provide a safer, more positive experience, lessening the risk of over-straining, injury, or collapse.

Methods

We conduct a large-scale data analysis of 10 years (2011 – 2019) of publicly available results data (n=423 496). We calculate how many runners experience slowdowns >25% somewhere during the race, and how many avoid losing time on the second half. We investigate differences between runners depending on age, sex, and ability. Furthermore, we calculate the relationship between temperature on the race day with the average finishing times and proportion of runners who hit the wall each year.

Results

Among recreational runners, men are about twice as likely to hit the wall compared to women, across all age groups and ability levels. Younger runners more likely to hit the wall than the middle-aged. In warmer years especially, more runners hit the wall, with a steeper increase among the men.

Conclusion

Using only easily accessible publicly available results- and weather data, we see that most runners loose time on the second half and would have benefited from pacing advice, especially in warmer years. Our results can be used by race organisers to provide advice to participants based on e.g., the weather prognosis on the race day, as well as estimating need for medical assistance.

Summary Box

What is already known on this topic

Many studies have investigated pacing for the full marathon distance, finding differences between age groups, sex, and ability, but few large-scale data analyses have on pacing patterns of finishers for half marathon exist. Half marathons have however been studied in the context of investigating the rate of collapses and need of ambulance assistance, where increase temperature increase risk.

What this study adds

Our contribution is a larger-scale data analysis on pacing of half-marathon finishers than previous with over 10 years of data from one of the world's largest half marathons. We highlight differences in pacing patterns based on age, sex, ability as well as temperature on the race day.

How this study might affect research, practice or policy

Race organisers and recreational runners may take interest in these results to provide advice about how to run a well-paced race, avoiding the risk of hitting the wall, injury or even collapse, especially when temperatures rise.

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INTRODUCTION

Every year over 40 000 runners participate in Gothenburg Half Marathon, one of the worlds largest half-marathons. Most participants are recreational runners of all ages and fitness levels, and many return to participate many times. An active lifestyle, including recreational running can contribute to public health [1]. It is therefore of interest to support runners pacing well for a pleasant experience, encouraging return participation while avoiding injuries, "hitting the wall" or in extreme cases collapsing. Our goal is to investigate if we can use a large database of historic public results to analyse what is indicative of both good and bad pacing performance: which runners manage to complete the race without losing time on the second half and which runners experience dramatic slowdown? We base our work on result data runners (n=423 496) for ten years (2010 – 2019) from Gothenburg Half Marathon where finishing times and 5 km split times are recorded. We follow a similar methodology as Smyth [2], where "hitting the wall" is defined as a > 25% drop in 5 km split time.

We find that there is room for improvement in pacing among recreational runners, most runners loose quite a lot of time on the second half of the race. Men are twice as likely as women to hit the wall, and runners below the age of 30 are more likely to hit the wall than middle-aged runners. However, among the younger runners there is also a larger share who manage to pace well and not loose time on the latter part of the race. Ability also plays a role, the proportion of runners hitting the wall increase with increased finishing time, as one would expect, while the converse is true for those running at a more even pace. Finish time and pacing is negatively affected by increasing temperatures, especially among men there is an increased risk of hitting the wall.

Our result can be used by race organisers to inform participants of risk factors affecting desired running pace. In the longer run these results could potentially also feed into the development of, for example, a personalised pacing app helping recreational participants finding a pace suitable for their own fitness level and the conditions on the day of the race.

Related Work

Gothenburg Half Marathon has been the subject of several previous studies investigating the incidence and characteristics of runners collapsing or requiring medical assistance [3, 4, 5], showing a higher incidence in warm years, and among younger runners. Similar studies have also been undertaken for half-marathons in South Africa [6, 7]. As opposed to these, we here instead look at pacing patterns for much the large group of runners who complete the race, and how they paced themselves between splits.

Several works investigate pacing patterns on the marathon distance, including the risk of large slowdowns based on e.g., age, sex, and ability [2, 8, 9, 10, 11]. Results points toward younger runners and men being more at risk of slowdowns and women generally pacing

more evenly. Cuk et al. also analysed the Vienna half-marathon in 2017 and found similar patterns [11, 10]. Ely et al. investigated the impact of weather and temperature on marathon finishing times [12], and found trends towards slowing with increased wet-bulb globe temperature. Trubee et al. finds that for non-elite marathon runners, women pacing better than men, and that this is magnified in hotter temperatures [13]. Many of the above studies on marathons use small to medium sized datasets, ranging from a few thousands up to 90 000 race records, except for [2], which use around 4 million records from different races. Our work covers over 400 000 race records, all from the same race over a 10-year period, which to our knowledge is one of the largest investigations of pacing patterns for a half-marathon.

DATA AND METHODS

Data

Our data consists of results from Gothenburg Half Marathon from the years 2010 – 2019 (earlier years did not have split times available). This data is publicly available from the race organisers website[1], we work with a snapshot of the underlying results database retrieved on 2 November 2021. Of relevance to analysis is the finish time, split times at 5, 10, 15 and 20 km, year of birth and sex. Each unique runner is identified by a unique numeric ID. In addition, we also added information about the temperature on the race day each year, obtained from the Swedish Meteorological and Hydrological Institute. As the runners start in different groups throughout the afternoon, we simply used the temperature at 3pm as actual temperature is assumed to be similar. The average daytime top temperature for Gothenburg in the month of May (when the race is held) is 17°C.

After pre-processing to removing entries with missing or obviously faulty information (e.g., missing/incorrect split- and finishing times) we obtain a dataset of 423 496 records (Female = 140 409, Men =283 087). As there are repeat participants, the dataset contains 184 890 unique individuals, on average participating 2,3 times in the ten-year period. Table 1 summarises the data by year.

Year	Runners	%Female	Temp °C	Average time		% HTW		% Neg Split	
				M	F	M	F	M	F
2010	37 982	29,0	21,7	02:03:59 ± 00:19:35	02:15:45 ± 00:19:22	16,7	5,7	5,3	6,7
2011	42 838	30,8	16,6	01:57:06 ± 00:18:27	02:09:59 ± 00:18:46	6,2	3,8	14,6	12,1
2012	42 838	31,2	13,6	01:56:04 ± 00:19:01	02:09:10 ± 00:19:05	7,1	4,4	15,1	12,5
2013	44 919	33,0	25,0	02:05:22 ± 00:19:53	02:16:46 ± 00:20:00	16,8	7,6	6,0	8,0
2014	47 187	34,6	18,9	01:59:38 ± 00:20:24	02:13:10 ± 00:20:18	12,4	7,2	6,8	6,5
2015	46 207	34,8	14,7	01:57:43 ± 00:20:00	02:10:45 ± 00:19:44	8,4	4,9	11,8	9,9

[1] https://reg.goteborgsvarvet.se/sok/resultatlista.aspx

2016	44 972	34,8	15,1	01:57:38 ± 00:20:00	02:11:16 ± 00:19:47	6,6	3,7	9,7	10,2
2017	42 252	34,5	13,9	01:57:27 ± 00:19:43	02:10:49 ± 00:20:03	6,0	3,8	14,3	12,6
2018	39 911	34,5	20,0	02:00:24 ± 00:21:17	02:14:40 ± 00:21:42	10,7	5,9	8,0	7,5
2019	33 134	34,0	19,4	01:59:58 ± 00:22:24	02:14:26 ± 00:22:05	11,1	6,7	8,2	5,4
Overall	**423 496**	**33,2**	**17,9**	**01:59:28 ± 00:20:14**	**02:12:33 ± 00:20:15**	**10,2**	**5,4**	**10,1**	**9,2**

Table 1: Summary of the data by year, number of runners, percentage of female runners, average finishing times and percentage of runners having hit the wall or run a negative split respectively. Coldest/warmest years highlighted.

Methods

To identify and compare pacing patterns we use two metrics defined below: the *Split Difference (SD)* capturing time gained or lost during the second half of the race, and the *Degree of Slowdown (DoS)* to identify any drastic slowdowns during any 5km split.

Split Difference

The Split Difference captures time lost/gained compared to maintaining the same pace held at the 10 km mark for the rest of the race. Note that as no exact mid-point split is available, we define SD as:

$$SD = FinishTime - 10kmSplit * 2{,}109775$$

Only 9,8% of runners overall manage to run an even (or negative) split, meaning that they maintain (or increase) their speed during the second half of the race, which is typically the recommended pacing pattern to achieve a good finish time on a half-marathon [14].

Hitting the Wall

We apply the operational definition by Smyth [2], where a 25% drop in pace between two splits is used as a proxy for having hit the wall. Even though hitting the wall is not a precise measure of the physiological state, there is not even a generally agreed upon precise definition [8, 15], it serves as an estimate of overextension which is undesirable.

The *base-pace (BP)* is defined as the average pace over the 5 and 10 km splits, as runners may experience congestion at the start of the race prohibiting them from directly matching the planned pace. Further, the risk of hitting the wall this early in the race is low. The BP is then compared to the degree of slowdown (DoS) for a segment *s* (10-15km, 15-20km or 20-21km), defined as the ratio of segment pace and base pace:

$$DoS(s) = \frac{pace(s) - BP}{BP} = \frac{pace(s)}{BP} - 1$$

Overall, 8,6% of runners in our dataset are classified as having hit the wall on some segment using this definition, most commonly between 15-20km. As expected, this is a smaller

proportion than in studies on marathon, as slowdowns during half-marathons more likely is due to lactate buildup or simply fatigue from overextension during the first half, rather than glycogen depletion.

Data Analysis
We use a Pythons scipy.stats library for statistical analysis. For pairwise comparisons we use a Fisher Exact test, and for multiple groups a chi-square test. Python scripts are available as supplementary material.

RESULTS

Pacing Patterns
Most runners loose time in the second half of the race, as illustrated in Figure 1 for runners with increasing finishing time. The fastest runners, finishing in less than 90 minutes, loose on average around 1:30 minutes on the second half, while an average runner, finishing in 120 minutes loose just over 4 minutes. Note that among the very fastest, it seems few run a negative split, possibly due to race tactics. In the groups with slower finishing times there is much more spread possible among the pacing strategies, but on average, slower finishers also lose more on the second half.

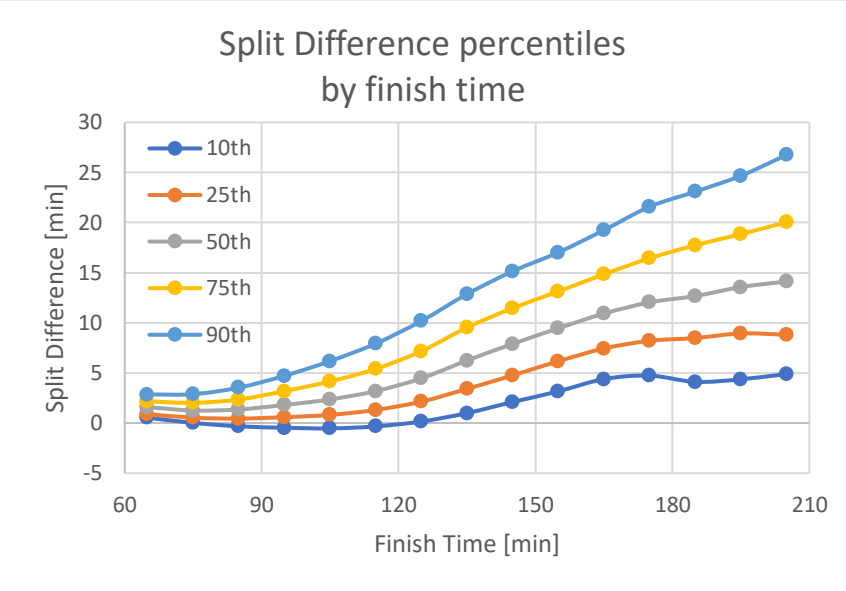

Figure 1. Average split difference (time lost on second half) as a function of finishing time (all runners) showing 10th, 25th, 50th, 75th and 90th percentile in finish time grouped by 10 minutes.

Average split differences are very similar between men and women, however grouping runners by finishing time shows the women consistently loose slightly less time for runners with finishing time > 90 minutes, see Figure *5* in the Appendix.

Older runners (50+) have a higher average finish time and split difference. However, grouping by finishing time shows no differences except among the slower runners (finish time > 150 minutes), where the younger age-groups in fact lose more time, see Figure *6* in the Appendix.

Who Pace Well and Who Hits the Wall?

Next, we investigate which runners, bases on sex, age, and ability, manage the best pacing strategy (achieving a negative or equal split), and conversely, which runners have failed with their pacing strategy and end up hitting the wall.

Sex

Men are twice as likely to hit the wall: 10,2% of male runners do so compared to just 5,4% of women (OR = 2,0, $p < 0,001$). Most runners will slow down during the second half of the race (see Table 1), but among runners managing a negative or equal split, male and female runners perform similarly: 10,1% of male runners and 9,2% of female do so (OR = 1,1, $p < 0,001$).

Age

Gothenburg Half marathon is open for participants aged 17 and above, with most runners being between 30-49 years old, see Table 2. Age information was missing or incorrect for 3173 datapoints, which were excluded from analysis.

Age	#Runners	% Female	% HTW		% Negative Split	
			M	F	M	F
17-29	89 031	44 %	13,0	7,0	14,7	12,3
30-39	125 484	33%	10,2	4,7	11,6	10,1
40-49	124 275	31%	9,0	4,2	9,0	7,7
50-59	62 261	27%	9,3	5,5	6,3	4,7
60 +	19 272	17%	9,9	5,4	4,4	3,0

Table 2: Share of male and female runners hitting the wall or managing a negative or equal split by age group.

The increased risk of hitting the wall for men compared to women is consistently high across all age groups), see Figure 2 ($1,74 \leq OR \leq 2,29$, $p < 0,001$. Both among women and men the youngest runners are most likely to hit the wall, while the 40–49-year-olds are least likely (female: OR = 0,59, male: OR = 0,66, $p < 0,001$). Differences between consecutive age groups within sex are significant except for the women in their 50's vs. 60's ($p = 0,74$).

A larger proportion of younger participants run a negative split, with men slightly higher than females consistently across age groups ($1,17 \leq OR \leq 1,49$, $p < 0,001$). This decreases for each older age group, see Figure 2 (pairwise between consecutive age groups, women: $0,58 \leq OR \leq 0,79$, men: $0,68 \leq OR \leq 0.76$, $p < 0,001$). The younger age groups are of course where we expect to find the elite or near-elite runners, who have the experience and fitness level to manage to keep a consistent pacing for a full half-marathon, but perhaps also many inexperienced recreational runners who start too fast and hit the wall.

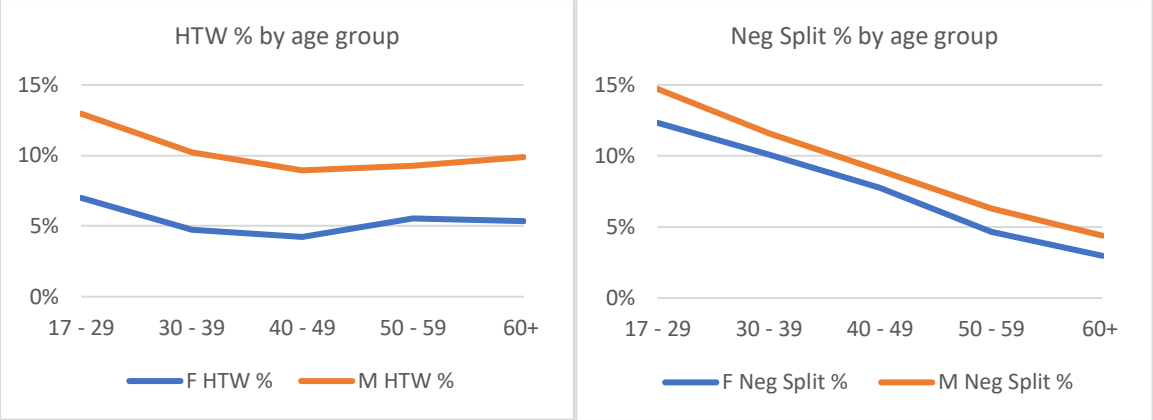

Figure 2. Proportion of male and female runners by age group hitting the wall (left) and running a negative split (right)

Ability

We find an increasing share of runners the slower the finishing time for both men and women (see Figure *7* in Appendix). For men, the share increases sharply for finishing times above 120 minutes, from less than 5% to over 30% among those finishing in over 150 minutes. The increase is less steep for women: for finishing times under 135 minutes less than 3% hit the wall, increasing to 25% for those finishing in over 180 minutes.

Conversely, the share of runners managing a negative split is highest among those finishing in 75-104 minutes for men (15-16%) and 90-119 minutes for women (14%), and then drops to 2-3% among the slowest runners Note that among the very fastest group very few (< 5%) run a negative split, possibly because of race tactics and placement being more important than finishing time.

Effect of temperature

With higher temperature there is a trend towards both higher finishing times and a larger proportion of runners hitting the wall. The average finish time and proportion of runners hitting the wall is lower in the five coolest years studies (< 18° C, small variation between years). As temperature increase, many runners manage to compensate for the by reducing their tempo (see Figure 3, female: r2 = 0,90, male r2 = 0,91, p < 0,001). The difference in average finishing time between the coldest (2012: 13,6° C) and the warmest (2013: 25° C) years is 7:36 min for women, and 9:18 for men.

In warmer years we see an increased share of male runners hitting the wall (r2 = 0,85, p < 0,001), see Figure 4. For women, the effect of temperature appears to be less of a factor (r2 = 0,66, p = 0,004). Regarding negative splits, data appears to fall into two clusters representing the five cooler years (< 18°) and the five warmer years (> 18°). Runners are about twice as likely (women OR = 1,74, men OR = 2,07) to manage a negative split in the five cooler years (see Appendix, Figure *8*).

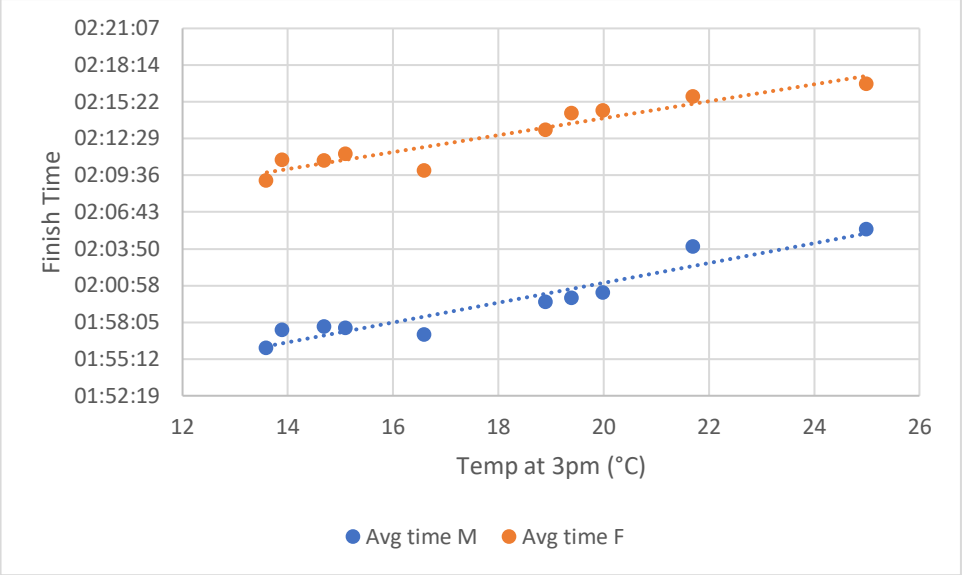

Figure 3. Average finishing time for male and female runners by temperature. Each point represent one year.

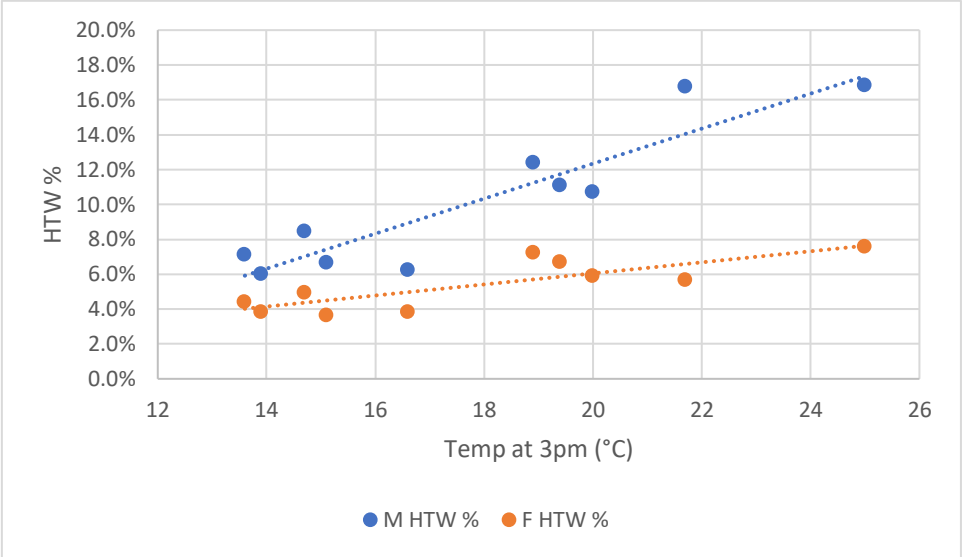

Figure 4. Percentage of male/female runners hitting the wall per year.

DISCUSSION

Our results show that many recreational half-marathon runners struggle somewhat with their pacing, and the majority lose time on the second half of the race. Men are twice as likely as women to overstretch themselves and hit the wall. Smyth [2] found similar patterns in marathon, although the effect size was smaller than in our work (OR=1.4 vs OR=2.0). We found a higher proportion of younger runners hitting the wall (age-group 17-29 years), with the lowest share among middle aged runners (40-49 years), which also has been shown in marathon studies [2, 9, 10, 11]. Carlström et al. [5] found that younger runners at Gothenburg Half Marathon (below the average age) were also more likely to require ambulance assistance. Studies on a half-marathons in South Africa has however found females over the age of 50 to have higher risk of medical complications [6], and that older females are less likely to finish the races [7]. Our data only consisted of runners completing

the race so we cannot say if the lower rate of hitting the wall among females could be because they instead abandon the race in such situations or not.

Temperature has a negative effect on both finishing times and the proportion of runners pacing themselves well. Men seem more adversely affected by increased temperature and both loose more time and increase the risk of hitting the wall more than women. Carlström et al. [5] found increased incidence of cases needing ambulances in years (2010-2016) with temperatures above 17°C, although naturally the cohorts are small. Our work finds the same patterns mirrored in the much larger cohort of runners that hit the wall during the race (see *Figure 9* in the Appendix), with the same notable peaks in 2010 and 2013. This indicates that race organisers may find the number of runners hitting the wall, which can be calculated from results data only, useful to estimate also need of ambulance assistance. Average finish times are faster and larger share of runners manages a negative or equal split pace in years below 18°C. This lends additional support for the conclusion of Carlström et al. that low-risk temperatures for half-marathons range between 13 – 18°C.

Limitations

Working only with public results data and split times comes with inherent limitations. Our metrics are do not include any personal metrics, reasons for slowdowns are unknown and thresholds for slowdown could be tweaked. Still, we believe these definitions serve as a good enough proxy for revealing trends in pacing, also seen in other studies [5]. With access to more fine-grained data e.g., GPS traces [8], HR monitors and training history, the models could be more exact. However, this incurs a cost of more involved data collection, and a risk of skewing data towards more ambitious runners carrying appropriate devices and recording their training history.

Conclusions and Further Work

Gothenburg Half Marathon is one of the words largest and gather many recreational runners, however, there seems to be room for improvement in pacing.
Working with a large dataset opens possibilities to apply machine learning techniques to the data, for example, predicting which runners risk hitting the wall before they do so. We have conducted some machine learning experiments based on the same data as here [16], to predict finishing times and identifying runners at risk of hitting the wall, based on factors identified in this work. The model correctly identifies many runners hitting the wall, but also many that do not. This is however a promising first step towards what could become a personalised pacing app. Including additional personal data, such as heart rate and training history will likely be beneficial for higher accuracy. In the meantime, we expect our results to help race organisers and recreational runners to mitigate common risks, and perhaps help run a more enjoyable half-marathon next time.

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APPENDIX: Pacing Patterns

Figure *5* shows the average split-difference for men and women by finishing time. For runners finishing on the same time, women generally loose less time on the second half than men.

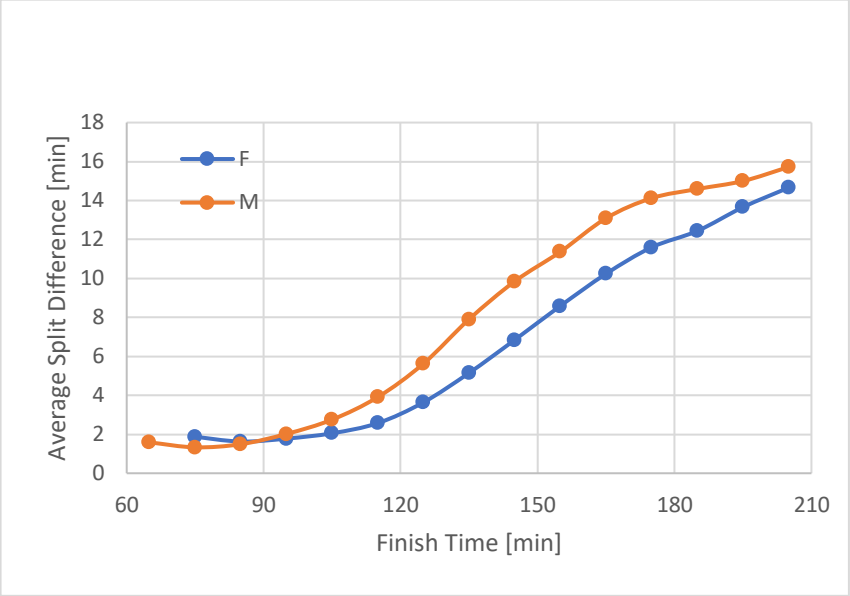

Figure 5. Average split difference by finishing time for male and female runners.

Figure *6* similarly illustrates time lost on the second half for four age groups. There is little or no difference among the faster runners. However, among the slower runners, with finishing times above 150 minutes, older runners seem to in fact loose less time than younger ones.

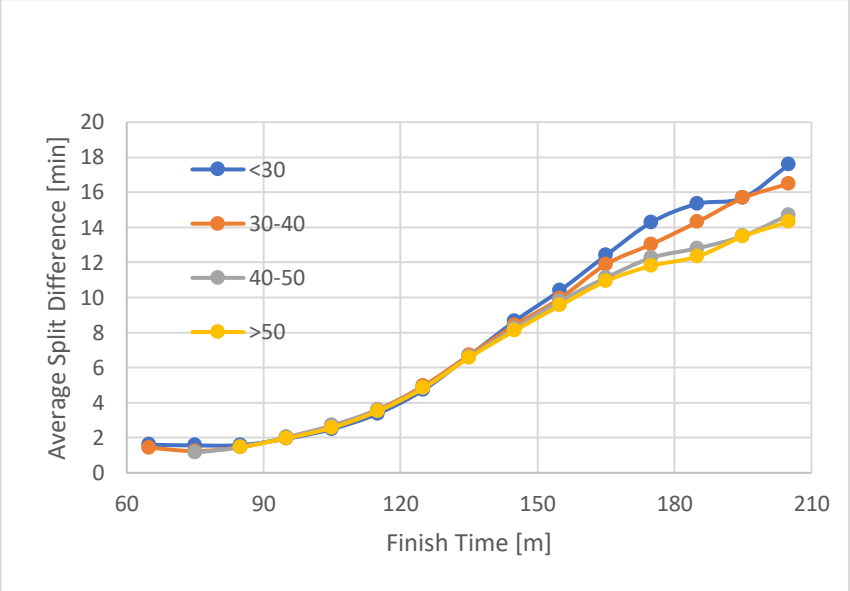

Figure 6. Average split difference by finishing time for different age groups.

Figure 7 illustrates the share of runners, grouped by finishing time who hit the wall and who runs a negative or even split. The share hitting the wall gradually increase with finishing time, which is not surprising, while the share of negative splits is higher among faster runners, except for the very elite where race tactics likely come into play, rather than optimising for as fast a time as possible.

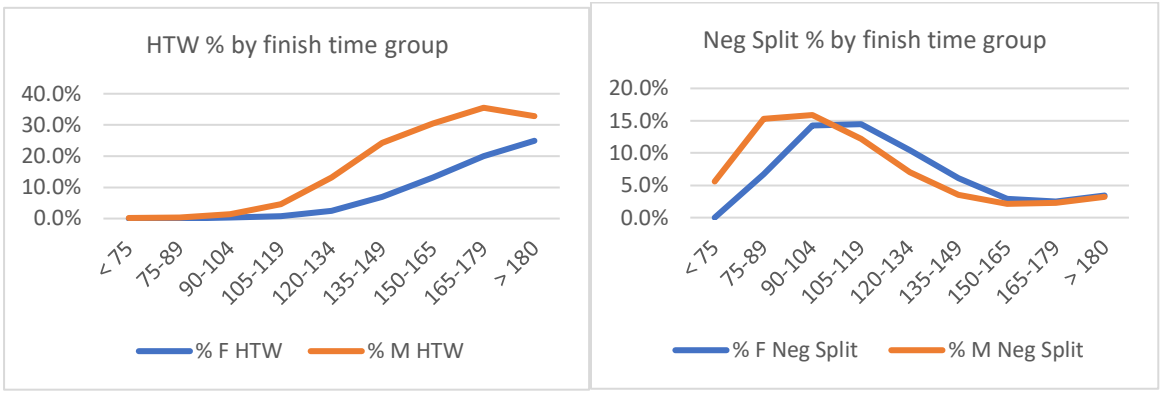

Figure 7: Proportion of runners hitting the wall or managing a negative split grouped by finishing time in minutes.

Figure *8* shows the share of male and female runners managing a negative or equal split, plotted against the temperature of the year in question. Data roughly falls in two clusters, where the five cooler years (< 18°C) have a larger share, and the warmer years (> 18°C) have a smaller share.

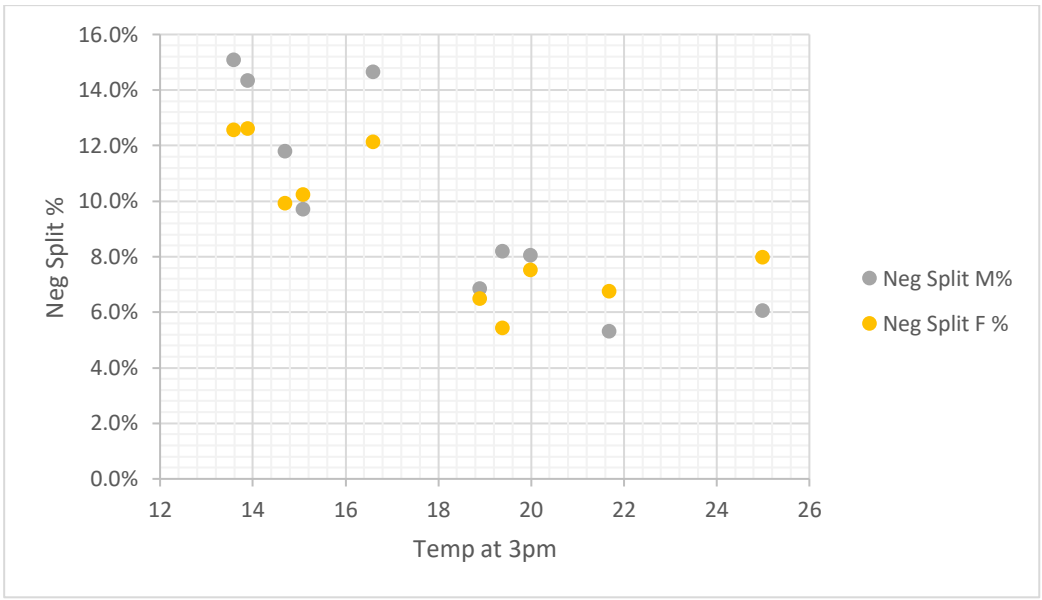

Figure 8. Share of male and female runners managing a negative or equal split per year.

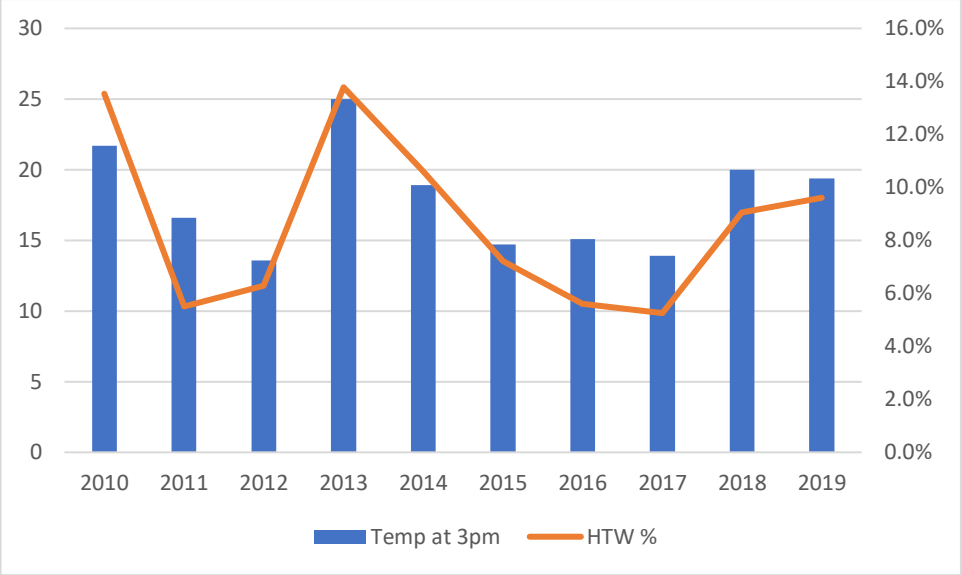

Figure 9. Proportion of runners hitting the wall each year, varies with temperature.