

# Devising a Pace-Based Definition for “The Wall”: An Observational Analysis of Marathoners’ Subjective Experiences of Fatigue

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**Context:** Many runners report “hitting The Wall” (HTW) during a marathon (42.2 km). However, the performance manifestation of this subjectively experienced phenomenon remains unclear.

**Objective:** To identify a pace-based classification for HTW by integrating subjective reports of fatigue and runners’ pacing profiles during a marathon.

**Design:** Cross-sectional study.

**Setting:** Public race event (2018 Dublin Marathon).

**Patients or Other Participants:** Eighty-three runners (28 [34%] women, 55 [66%] men, age =  $41.5 \pm 9.1$  years, height =  $1.73 \pm 0.09$  m, mass =  $70.2 \pm 10.1$  kg).

**Main Outcome Measure(s):** The pacing profiles for respondents to our postrace questionnaire that concerned the phenomenon of HTW were evaluated. Receiver operating characteristic analyses were performed on discretized outcomes of the time series of marathoners’ paces during the race.

**Results:** Using the receiver operating characteristic analyses, we observed that runners could be classified as having

experienced HTW if they ran any 1-km segment 11% slower than the average of the remaining segments of the race (accuracy = 84.6%, sensitivity = 1, specificity = 0.6) or if the standard deviation of the normalized 1-km split times exceeded 0.0532 (accuracy = 83%, sensitivity = 0.818, specificity = 0.8). Similarly, runners could be classified as having experienced HTW if they ran any 5-km segment 7.3% slower than the average of the remaining 5-km segments of the race (accuracy = 84.6%, sensitivity = 1, specificity = 0.644) or if the standard deviation of the normalized 5-km split times exceeded 0.0346 (accuracy = 82%, sensitivity = 0.909, specificity = 0.622).

**Conclusions:** These pace-based criteria could be valuable to researchers evaluating HTW prevalence in cohorts for whom they lack subjective questionnaire data.

**Key Words:** running, sports, exercise, physical fitness, physical endurance, endurance training

## Key Points

- For a 1-km split-time resolution, runners could be classified as having experienced “hitting The Wall” (HTW) if they ran any 1-km segment 11% slower than the average of the remaining segments of the race or if the standard deviation of the normalized 1-km split times was  $>0.0532$ .
- For a 5-km split-time resolution, runners could be classified as having experienced HTW if they ran any 5-km segment 7.3% slower than the average of the remaining 5-km segments of the race or if the standard deviation of the normalized 5-km split times was  $>0.0346$ .
- Researchers, coaches, and athletes can adopt these thresholds to evaluate the prevalence of HTW among groups of athletes without subjective questionnaire data.
- A greater variety of marathon courses, environmental conditions, and participant demographics should be examined to devise a more definitive pace-based definition of HTW.

The marathon (42.2-km) footrace is one of the most popular sporting events worldwide for athletes of both sexes and various ages and abilities. In the past 2 decades, the number of United States runners has almost quadrupled. In each year between 2004 and 2016, an average of 470 000 runners (approximately 42% female) completed a marathon in the United States alone,<sup>1,2</sup> with consistent participation rates across years.<sup>3</sup>

Recently, race record datasets for numerous city marathon events have been made available online.<sup>4</sup> This has enabled researchers and the public to examine the races of elite and recreational runners, gaining new insights into

the characteristics of the participating groups and their associated in-race splits and overall finish times.<sup>5</sup> For instance, in analyses of the race records from the Boston, Chicago, and London marathons, researchers<sup>4,6,7</sup> demonstrated that marathoners who finished the 42.2-km distance in  $<3$  hours typically had an even or negative split time<sup>4,6,7</sup> between the first and second halves of the race. In contrast, marathoners who exhibited a positive split<sup>4,6,7</sup> tended to finish in  $>3$  hours.

Based on these data, it is clear that *pacing*, or the actual distribution of speed, power output, or energetic reserves during a given sporting event,<sup>8</sup> is a fundamental determi-

nant of competitive endurance performance.<sup>9,10</sup> A phenomenon widely recognized as disrupting marathoners' pacing is associated with extreme fatigue and is known as "hitting The Wall" (HTW). It has been attributed to a combination of factors: peripheral fatigue, affecting the exercising skeletal and heart musculature; central fatigue, affecting the brain with either the accumulation of excessively high concentrations of neurotransmitters or the depletion of other critical neurochemicals; and self-regulatory fatigue, where increasing levels of perceived exertion and discomfort modify the regulation of neuromuscular recruitment and voluntary exercise behavior.<sup>11</sup> The multifaceted nature of HTW has led to a lack of clarity on what this phenomenon is or how it should be practically defined for its influence on runners' paces.

Buman et al<sup>12</sup> evaluated the phenomenon of HTW in 315 marathoners via a postrace questionnaire. The salient characteristics of "The Wall" were described by the 43% of participants who reported HTW during the marathon; subjective reports of "generalized fatigue, unintentionally slowing pace, desire to walk, and shifting focus to survival" were strongly correlated with the phenomenon.<sup>12</sup> These were the first researchers to formally define The Wall during a marathon. In a follow-up study, Buman et al<sup>13</sup> determined that The Wall occurred with increasing probability up to 32 km of the marathon distance and with decreasing probability from 33 km to 42 km. Although these authors were the first to devise a quantifiable means for identifying instances of HTW, they did not evaluate the marathoners' associated pacing. Therefore, the performance manifestation of HTW remains unclear. It may not be possible to comprehensively define all HTW instances due to its multifactorial nature, but the elucidation of a pace-based criterion specific to the marathon could be valuable to runners, coaches, and researchers in instances when subjective questionnaire data are not available. This would allow runners, coaches, and researchers to determine the prevalence of HTW in different marathons or under various environmental conditions when subjective questionnaire data are not available. Thus, we aimed to address a hypothesis-generating research question to advance current knowledge on the performance manifestation of the subjectively defined phenomenon known as The Wall during a marathon. Specifically, we administered a postrace questionnaire to marathon participants to determine whether they experienced HTW and subsequently evaluate their pacing profiles to devise a pace-based threshold for The Wall for the marathon. We hypothesized that it would be possible to accurately classify HTW occurrences (defined subjectively) on the basis of marathoners' paces.

## METHODS

### Participants

Participants were recruited at convenience during the Dublin Marathon Expo 2018 held October 26–27, 2018. Prospective participants in the KBC Dublin Marathon 2018, which was held on October 28, 2018, were required to attend this event to pick up their race numbers and race chips, which were needed to obtain an official time in the race. Floor space was rented in the preceding months, and members of the research team were stationed at a stand during the event. Attendees who approached the stand were

informed of the researchers' intent to conduct a study of marathon running. Volunteers were not eligible for the study if they were <18 years of age. All participants provided written informed consent, and the study was approved by the Human Research Ethics Committee-Sciences of our university (reference: LS-17-77).

### Protocol

Participants were instructed to complete a short on-site questionnaire, documenting their race number, age, basic anthropometric measures (height and mass), training behavior, most recent race times (10 km, 10 mi, or half marathon), marathon experiences, and target finish times and provide their e-mail address. They were informed that their e-mail addresses would be used to send a postrace questionnaire related to their marathon experience. Runners with target times >4 hours and 30 minutes were deemed ineligible to exclude individuals with a walk-run marathon-pacing strategy.

Racers were sent the postrace questionnaire 48 hours after the marathon. The postrace questionnaire was used to ascertain symptoms of HTW, as identified by Buman et al,<sup>12</sup> and delivered via a Google Form (Google LLC, Mountain View, CA) link (Table 1).

Participants were also instructed to provide a means to access, where available, any global positioning system (GPS) tracking data acquired via a smartphone or wearable device and subsequently logged in a self-monitoring platform, such as Strava (San Francisco, CA). Participants' race numbers were required to facilitate cross-checking of their in-race split times via the 2018 Dublin Marathon's Web site.<sup>14</sup>

The Wall phenomenon was not discussed with prospective participants. Only postrace responses recorded within 1 week of the race were eligible for analysis to minimize the potential effect of recall bias. Recruits were not compensated for taking part in the study.

### Race Details

The marathon started at 9:00 AM on October 28, 2018. The temperature during the race was between 3°C (9:00 AM) and 10°C (1:30 PM). Wind conditions were northerly at 11 to 17 km/h, and the relative humidity was 76% to 87% with scattered clouds.

### Outcomes

We input data gathered from the prerace questionnaire into a spreadsheet to document each participant's actual finish time based on the race records; target time; and a predicted time, derived from race and training data, using the equations described by Vickers and Vertosick.<sup>15</sup> The postrace questionnaire asked whether participants experienced HTW during the marathon. They were instructed to report whether they experienced any of the 4 symptoms: generalized fatigue, unintentionally slowing of pace, desire to walk, or shifting focus to survival.<sup>12</sup> They were deemed to have experienced HTW if they reported any 3 of the 4 symptoms described by Buman et al.<sup>12</sup>

We retrieved the times for all marathon finishers (10 672 men, 5537 women). Using their race numbers, we identified the subset of respondents to the postrace questionnaire and extracted their in-race split and overall finish times. The

**Table 1. Postrace Questionnaire<sup>a</sup>**

1. Did you finish the marathon?
2. Please indicate whether you experienced the below characteristics/feelings to a degree significantly more than you would normally experience during a distance race or long run. Tick all that apply:  
 Generalized fatigue  
 Unintentionally slowing pace  
 Desire to walk  
 Shifting focus to survival

<sup>a</sup> Instrument is presented in its original format.

time in each split (10 km, 21.1 km, 30 km, and 42.2 km) was normalized to the distance covered so that each split could be compared over a distance of 10 km. Specifically, the time spent in segment 2 was divided by 1.10975 (21.0975 km – 10 km), in segment 3 was divided by 0.89025 (30 km – 21.0975 km), and in segment 4 was divided by 1.2195 (42.195 km – 30 km). Each split time was then divided by the associated finish time to facilitate pooling of participants with different finish times.

When self-monitored GPS tracking data were also available for each 1-km segment of the race, they were cross-referenced with the official in-race split times to ensure accuracy, and, if they matched, the 2 datasets were combined. The 1-km split times were adjusted for course gradient using the method described by Minetti et al.<sup>16</sup>

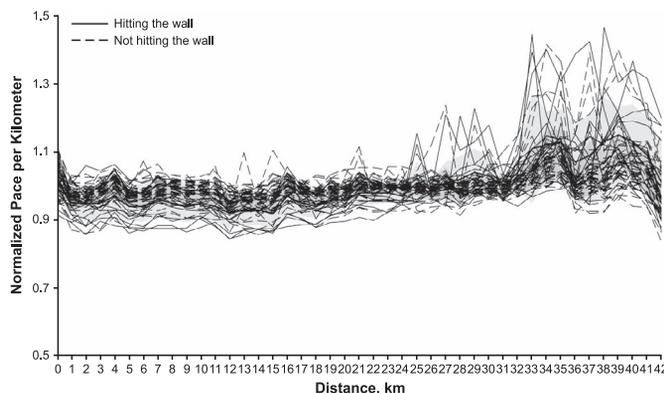
To maximize the utility of a pace-based threshold for HTW, we devised thresholds for split resolutions of 1-km, 5-km, 10-km, or first- versus second-half race times where available. To achieve this, in-race split data were discretized in the following manner:

- (1) by calculating the standard deviation (SD) in the split time (1-km, 5-km, 10-km, and first- versus second-half split resolutions separately);
- (2) by dividing the time to complete the slowest split by the average of the remaining splits (1-km, 5-km, and 10-km split resolutions separately);
- (3) by dividing the second-half race time by the first-half race time (first- versus second-half split resolution only).

The 10-km and 1-km split-time data before discretization are presented in Figure 1.

**Data Analysis**

**Participant Characteristics.** Respondents and nonrespondents to the questionnaire were compared using



**Figure 1. Normalized split-time data before discretization. Group means for each time series are illustrated with bold lines. Normalized pace per kilometer was defined as the pace in a kilometer divided by the average pace per kilometer for the entire race.**

independent-samples *t* tests for each variable to assess representativeness. The  $\alpha$  level for this analysis was set at .05.

**Receiver Operating Characteristic Analysis.** The predictive capacity of discretized data in classifying HTW instances was quantified via logistic regression and a receiver operating characteristic (ROC) curve analysis. Accuracy was quantified via the C statistic, which measures the area under the ROC curve.<sup>17</sup> The  $\alpha$  level for this analysis was set a priori using a Bonferroni-adjusted correction for multiple comparisons at .0167 (0.05/3 [discretization methods]). All data were analyzed using SPSS (version 18; SPSS Inc, Chicago, IL).

**RESULTS**

**Participant Characteristics**

A total of 237 marathoners (83 [35%] women, 154 [65%] men) who were registered for and intended to take part in the marathon were recruited at the expo event. Of these, 83 (35%) marathoners (28 women, 55 men) completed the postrace questionnaire within 1 week of administration. The characteristics of the respondents and nonrespondents, in addition to the results of the statistical comparison for each characteristic, are presented in Table 2. In summary, we observed no differences between respondents and nonrespondents to the questionnaire.

**Table 2. Participant Characteristics Delineated by Respondents and Nonrespondents to the Postrace Questionnaire**

Characteristic	Mean $\pm$ SD (Range)		P Value
	Respondents	Nonrespondents	
Age, y	41.5 $\pm$ 9.1 (21–68)	42.6 $\pm$ 7.6 (21–58)	.07
Height, m	1.73 $\pm$ 0.09 (1.42–1.92)	1.74 $\pm$ 0.09 (1.52–1.90)	.44
Mass, kg	70.2 $\pm$ 10.1 (44–100)	72.9 $\pm$ 10.5 (51–98)	.67
Time, min			
Target	221 $\pm$ 33 (145–330)	222 $\pm$ 30 (150–299)	.37
Actual	229 $\pm$ 38 (150–358)	223.78690 $\pm$ 42.22584 (146–337)	.83
Predicted	225 $\pm$ 29 (NA)	223 $\pm$ 32 (NA)	.74
Difference between target and actual times, min	8 $\pm$ 18 (–32 to –132)	4 $\pm$ 41 (–218 to –271)	.63
Difference between predicted and actual times, min	0 $\pm$ 14 (NA)	–5 $\pm$ 14 (NA)	.60

Abbreviation: NA, not applicable.

**Table 3. Respondent Characteristics Stratified by Hitting the Wall or Not Hitting the Wall**

Characteristic	Hitting the Wall	Not Hitting the Wall
Sex, No., men/women	14/1	41/27
	Mean (95% Confidence Interval)	
Age, y	40 (32, 48)	41 (38, 43)
Height, m	1.63 (1.36, 1.90)	1.66 (1.58, 1.75)
Mass, kg	71 (59, 84)	66 (61, 71)
Body mass index, kg/m <sup>2</sup>	25 (24, 25)	24 (23, 24)
Marathon experience, No.	1.92 (0.64, 3.20)	4.12 (2.73, 5.51)
Time, min		
Target <sup>a</sup>	242 (230, 254)	218 (211, 225)
Actual <sup>a</sup>	255 (236, 273)	221 (214, 229)
Predicted <sup>a</sup>	241 (230, 251)	222 (215, 229)
Actual target	13 (1, 24)	2 (0, 3)
Actual predicted <sup>a</sup>	10 (1, 19)	-2 (-5, 2)

<sup>a</sup> Denotes between-groups difference.

Excluding the 83 respondents to our postrace questionnaire, 16 126 runners took part in the marathon (5509 [34%] women, 10 617 [66%] men), the average finish time was 256 minutes (4 hours, 16 minutes)  $\pm$  50 minutes, and the mode finish time was 238 minutes (3 hours, 58 minutes). Formal statistical comparison between respondents and nonparticipants was not deemed appropriate, as we sought to exclude individuals with a walk-run pacing strategy for the purpose of defining HTW.

Fifteen (18%) of the 83 runners were deemed to have experienced HTW. The GPS data, including 1-km split times, were available for 56 (67%) of the 83 respondents (14 respondents who experienced HTW and 42 respondents who did not experience HTW; Table 3).

### The ROC Curve Analysis

Results of the direct logistic regression and ROC curve analyses identified predictive values for the following discretized variables:

- (1) the time to complete the slowest split relative to the remaining splits (1-km [accuracy = 84.6%, sensitivity = 1, specificity = 0.6,  $P < .001$ ] and 5-km [accuracy = 84.6%, sensitivity = 1, specificity = 0.644,  $P < .001$ ] splits);
- (2) the SD in the split time (1-km [accuracy = 83%, sensitivity = 0.818, specificity = 0.8,  $P = .001$ ] and 5-k [accuracy = 82%, sensitivity = 0.909, specificity = 0.622,  $P = .001$ ] split resolutions).

The results of the ROC curve analysis for all discretized variables are presented in Table 4. The cutoff for HTW at the 1-km split resolution for SD was 0.0532 and at the 5-km resolution was 0.0346. The cutoff for HTW at the 1-km split resolution for the slowest relative segment was 1.1107 and at the 5-km resolution was 1.0731. The ROC curves are plotted for the combined set of discretized variables in Figure 2.

### DISCUSSION

The purpose of our study was to devise a pace-based criterion for HTW. Instances of HTW were identified via a postrace questionnaire, based on the findings of Buman et al.<sup>12</sup> Using their results and specifically any 3 of the 4 symptoms of generalized fatigue, unintentionally slowing of pace, desire to walk, or shifting focus to survival, we observed a 16% prevalence of HTW in our group of postrace questionnaire respondents. Using logistic regression and ROC curve analyses, we identified the pacing profiles associated with HTW for the 1-km and 5-km split-time resolutions. Specifically, by comparing any single 1-km segment with the remaining 41 1-km segments of the marathon (1-km split-time resolution) or any single 5-km segment with the remaining 7 5-km segments of the marathon (5-km split-time resolution), we classified instances of HTW by cross-referencing questionnaire responses with these split resolutions for each participant.

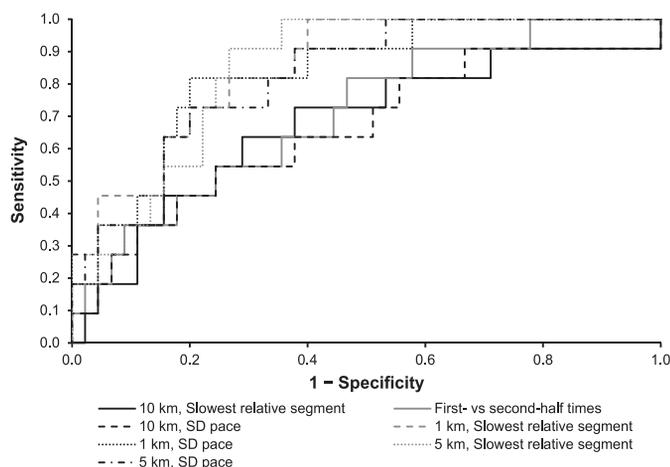
Based on a 1-km split-time resolution, runners were classified as having experienced HTW if they ran any single 1-km segment 11.07% slower than the average of the remaining 41 1-km segments of the race (accuracy = 84.6%, sensitivity = 1, specificity = 0.6) or if the SD of the normalized 1-km split times exceeded 0.0532 (accuracy = 83%, sensitivity = 0.818, specificity = 0.8). Based on a 5-km split-time resolution, runners were classified as having experienced HTW if they ran any single 5-km segment 7.3% slower than the average of the remaining seven 5-km segments of the race (accuracy = 84.6%, sensitivity = 1, specificity = 0.644) or if the SD of the normalized 5-km split times exceeded 0.0346 (accuracy = 82%, sensitivity = 0.909, specificity = 0.622). Although none of the 21.1-km or 10-km split-resolution thresholds were different based on our Bonferroni-adjusted a priori  $\alpha$  ( $P = .0167$ ), completing the second half of the race 4.3% slower than the first could be used to correctly classify 70.7% of HTW cases (sensitivity = 0.818, specificity = 0.533,  $P = .04$ ) at the level of  $P < .05$ . These pace-based thresholds could be valuable to researchers evaluating the prevalence of HTW

**Table 4. Results of the Receiver Operating Characteristic Curve Analyses for All Discretized Variables**

Resolution, km	Discrete Variable	Accuracy	Sensitivity	Specificity	Cutoff	Standard Error	<i>P</i> Value	95% Confidence Interval
21.1	First- vs second-half time <sup>a</sup>	0.707	0.818	0.533	1.0433	0.084	.04	0.543, 0.872
10	Slowest relative segment <sup>b</sup>	0.673	0.727	0.622	1.0445	0.097	.08	0.483, 0.863
	SD pace	0.659	0.545	0.756	0.0094	0.098	.11	0.466, 0.851
5	Slowest relative segment <sup>b</sup>	0.846	1	0.644	1.0731	0.053	<.001	0.744, 0.949
	SD pace	0.820	0.909	0.622	0.0346	0.062	.001	0.698, 0.942
1	Slowest relative segment <sup>b</sup>	0.846	1	0.6	1.1107	0.055	<.001	0.738, 0.955
	SD pace	0.830	0.818	0.8	0.0532	0.062	.001	0.708, 0.953

<sup>a</sup> Calculated by dividing the second-half race time by the first-half race time.

<sup>b</sup> Calculated by dividing the time to complete the slowest split by the average of the remaining splits (1-km, 5-km, and 10-km split resolutions separately).



**Figure 2.** Receiver operating characteristic curve for each discretized variable.

in cohorts for whom they lack subjective questionnaire data.

Subjective reports of perceived fatigue are an important foundation for defining HTW because runners experience fatigue differently. Researchers have presented HTW as a phenomenon that is only experienced by recreational or subelite runners,<sup>18</sup> and the runners' physiology and background in endurance events are both likely to influence this experience.<sup>19</sup> Although this might imply that HTW is to some extent unmeasurable, the degree of accuracy with which discretized measures of pacing could be used to classify HTW instances in our study, defined by high ratings of perceived exertion, suggests that the phenomenon is to some extent quantifiable, both subjectively and by observable performance, despite the underlying subjectivity of the experience. This is further evidenced by our analysis of each group's target, predicted, and actual finish times. Although we found no between-groups difference between target and actual finish times (ie, both groups reached their target finish times), participants who experienced HTW finished slower. From this information, we could deduce that participants who experienced HTW finished slower because they were simply less capable or trained less well for the race. However, the participants who experienced HTW were also less likely to achieve their predicted times, which were derived based on their self-reported training histories (Table 3). These predicted times can be considered to represent the extent to which participants fulfilled their potential, whereby faster predicted times were derived by having higher average weekly training distances and faster historical race times. Combining these findings, we posit that the greater difference between the predicted and actual finish times of participants who experienced HTW represents a negative effect of HTW, whereby, despite training adequately to achieve their predicted times, an HTW event disrupted this prediction and was associated with a slower finish. Although the causality of the relationship between pacing and HTW cannot be inferred using our results, previous researchers<sup>20</sup> demonstrated that aggressive early pacers are more likely to experience large slowdowns later in the race. Therefore, pacing and the occurrence of HTW are likely interdependent, whereby incorrect pacing in the early stages of a marathon might

increase one's risk for HTW later, which itself manifests in an undesirable slowdown in pace. Our findings provide a means of quantifying how much of a pace slowdown is associated with HTW and how this is linked with slower finish times.

Despite the insights provided by the pace-based thresholds for HTW, the results of our study are not definitive and cannot be used to prevent instances of HTW or ascertain at what stage of the race people experience HTW or be leveraged to draw any causal inferences as to why it occurs. Given the personal and contextual factors associated with each marathon, a comprehensive understanding of The Wall will vary with each subjective experience. Variables not measured as part of our analysis, such as a marathoner's prerace<sup>21</sup> and in-race nutrition strategies,<sup>22</sup> are probably important contributors to overall performance on race day. We illustrated that a definitive pace-based classification of The Wall (with accuracy levels approaching 100%) is probably an unrealistic pursuit due to the variability of its underlying subjective perception but that this subjectivity is nonetheless important when seeking to devise any such classification. In our study, by classifying HTW using subjective symptoms, we captured the heterogeneity of its physical manifestation, improving the external validity of these results.

In a practical sense, runners and coaches should acknowledge that although HTW cannot be fully understood, they should not be dissuaded from attempting to mitigate its symptoms during their preparation for a marathon event. Specifically, using cognitive strategies, including if-and-then implementation strategies, has been advocated by researchers.<sup>23</sup> Elite runners who used associative cognitive strategies coped better with pain during a marathon compared with nonelite runners who tended to rely on dissociative strategies.<sup>19</sup> Furthermore, a few investigators<sup>22</sup> have shown that runners who consumed carbohydrate fuel during the race were less likely to experience HTW. Although we could not monitor our participants' adherence or nonadherence to such strategies, our data showed that it may be possible to prevent HTW and, by extension, decreased performance. Extrapolating these findings to our results, marathoners would be more likely to reach their predicted finish times by adopting an appropriate in-race nutrition strategy because they would be less likely to experience HTW.

We sought to maximize the external validity of our results through a variety of means, but some potential limitations should be acknowledged. First, the accuracy of the estimates of training behavior provided by our participants was an important consideration, as self-report sampling is potentially associated with more measurement error.<sup>24</sup> However, self-report training logs and diaries have consistently been used to determine the frequency, duration, intensity, and type of exercise exposures for a variety of outcomes<sup>25</sup> and have been accurate when describing exercise.<sup>26</sup> Attempts to reconcile data garnered via self-reporting with direct measures, such as GPS tracking devices, have indicated that the error associated with subjective determination is random.<sup>27</sup> Therefore, we are confident that any potential "noise" associated with self-report measures is unlikely to have made a meaningful difference in the accuracy or representativeness of the dataset.

Second, our pace-based classification of The Wall was derived from the grade-adjusted pacing profiles<sup>16</sup> of the respondents to our questionnaire. The advantage of grade-adjusted pace is that it includes the elevation profile of the marathon course. Despite our efforts to limit the effect of this confounder, it is possible that our participants' paces, and, therefore, the pace-derived classification of The Wall, depended in part on the elevation profile of the course, thereby limiting its applicability to other marathons. It is also possible that the definition of HTW, whether determined by pace or the administration of a subjective questionnaire, will always be partially dependent on the marathon itself. Defining The Wall on a per-marathon basis may not be feasible; however, it would be prudent to investigate the potential variability of what constitutes The Wall for a group of marathons with various elevation profiles and environmental conditions in future studies. Researchers have elucidated a relative performance difference for marathons in different locations under different environmental conditions,<sup>28</sup> substantiating this presumption.

Third, although we sought to recruit a large representative sample covering the full spectrum of running ability (the fastest runner in our cohort finished in 2 hours and 30 minutes, and the slowest runner finished in 5 hours and 58 minutes), the external validity of our pace-based threshold of The Wall was limited by the relatively small sample of participants from only 1 marathon and the resulting constraints. For instance, the environmental conditions may have substantially affected the pace-based threshold of The Wall, but this cannot be elucidated using our dataset. We also sought to limit our cohort to participants who intended to run the entire marathon, hence our decision to exclude runners aiming for a finish time of >4 hours and 30 minutes. Future researchers building on our findings should replicate this study in larger samples of marathoners at a more diverse group of marathons.

## CONCLUSIONS

We presented a pace-based threshold for HTW that can be applied when the subjectively reported data required to definitively determine the presence of this phenomenon on an individual basis are not available. Specifically, our findings suggested that, based on a 1-km split-time resolution, runners can be classified as having experienced HTW if they ran any 1-km segment 11.07% slower than the average of the remaining segments of the race or if the SD of the normalized 1-km split times exceeded 0.0532. For a 5-km split-time resolution, runners can be classified as having experienced HTW if they ran any 5-km segment 7.3% slower than the average of the remaining 5-km segments of the race or if the SD of the normalized 5-km split times exceeded 0.0346. These thresholds can be adopted by athletes, coaches, and researchers in any evaluation of HTW prevalence among groups of athletes for whom subjective questionnaire data are not available; however, future researchers should expand the methods presented here to include a greater variety of marathon courses, environmental conditions, and participant characteristics if a more definitive pace-based definition of The Wall is to be devised.

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