Long Walk

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The long-walk from Phoenix, Arizona to Malibu, California on the paved Interstate Highway 10 stretches for 407 miles (or 655.003 km).

A common estimation for walking stride length based on a person's height is to multiply the height in cm by 0.415 for men or 0.413 for women, roughly 42% (Barreira, Rowe, & Minsoo, 2010; Crosby, n.d.; Science Buddies, 2013). Barreira et al. (2010) studied the average heart rate, speed, stride length, and stride rate in healthy young adults and noted that Hatano's and Bassett's 42% multiplier method is not the most accurate. When possible, it is better to use a pedometer and measured walking distance to calculate the stride length (Barreira et al., 2010).

For a male subject (male-X) whose height is 5 foot and 10 in (177.8 cm), the approximate stride length (SL) would be SL = 0.415 * 177.8cm = 73.747cm or 0.73787 meters which falls within range of Barreira's et al. (2010) average mean stride length of 0.78m +/- 0.05 (standard deviation) in their walking and jogging study.

Tudor-Locke and Rowe's (2012) review study on walking cadence and free-living ambulatory behavior found that normal adult male (18-49 year old) normal (recreational or street) walking cadence is 91-135 steps/minute or 45.5 - 67.5 strides/minute. Taking into account the male subject's stride length along with Tudor-Locke and Rowe's (2012) pedestrian cadence, the male subject (male-X) is likely to walk (casual pedestrian speed) at 2.01 km/hr - 2.99 km/hr or 1.25 miles/hr - 1.86 miles/hr. Tudor-Locke and Rowe (2012) noted that moderate intensity walking (3.0-3.5 Metabolic Equivalent or MET) is around 2.5-3.2 miles/hr (Compendium of Physical Activities, n.d.; Tudor-Locke & Rowe, 2012; Word Health Organization). In comparison, backpacking/hiking is higher intensity and rated at 7.0-7.8 METs by the

Compendium of Physical Activities (n.d.). For the long walk on Interstate Highway 10, unimpeded by crowds and other urban structures/distractions, it would be reasonable to expect male-X (5'10", 154 lbs) to walk at 4 km/hr carrying a pack.

Variations of Naismith's rule have been used in hiking, orienteering, expedition planning, and other activities that need to consider route choice and the duration of travel (Scarf, 2007; Scarf & Grehan, 2005). After his 1892 expedition, William Naismith (a Scottish mountaineer) developed a method to estimate a trip's travel time taking into account distances on the flat and on ascent (Naismith's rule, n.d.; Scarf, 2007; Scarf & Grehan, 2005). Assuming hikers were in "fair condition" and a hiking difficulty of Class 1 (trail-walking on paved concrete to the easier end of alpine trails, no to low difficulty on foot-balance) on the Yosemite Decimal System (ranking hike/trail difficulty), Naismith found that estimating 1 hour for every 3 miles on the map and adding 1 hour for every 2000 ft of ascent was fairly accurate (Colorado Mountaineering, 2012; Scarf, 2007).

Using the online Naismith's rule calculator by Wild Walks (http://www.wildwalks.com/bushcraft/technical-stuff/naismith-s-rule-estimate-walking-time.html) with the values of distance = 655.003 km, walking speed = 4 km/h, total climbing ascent = 1934.2 meters (from Phoenix, AZ to Malibu, CA), total descent = 2216.9 meters; the walk from Phoenix, AZ to Malibu, CA will take at least 168 hrs and 49 min to complete with no breaks/rests figured into the estimation. If the subject male-X were to walk around the clock without stopping, it would take him 7 consecutive days of walking to reach Malibu.

Total ascent and descent (meters) values for the Naismith's rule calculator were calculated by sampling 30 points along a path on Interstate Highway 10 from Phoenix, AZ to

Santa Monica, CA (the terminus of Interstate Highway 10) using the elevation calculator by Google map developers (refer to data in appendix).

How much walking can one do in a day? The answer obviously varies by individuals taking into account fitness, fatigue, physical status, social factors, environmental factors, and situations beyond one's control. Justin Kuhel (Camp Lejeune, NC to Camp Pendleton, CA) averaged 23.1 miles per day (approximately 9.5-10 hrs/day at 4km/h) (March Across America, n.d.). Ameranth (from Maryland to California) averaged 15-25 miles per day (Ameranth, n.d.). Nate Damm started walking around 13 miles per day and ended the journey around 25 miles per day (Damm, n.d.). Generally, it may be fair to expect anywhere from 6 to 10 (average) hours of walking per day. In contrast to the long walk problem, these real-world individuals were also allowed to buy supplies, use a stroller or push-cart, stay at motels or other lodging, and replenish/discard items from their travel inventory.

In contrast, the well-known ultra-endurance, ultramarathon man Dean Karnazes has run 350 miles continuously, without sleep and has run in Death Valley and the South Pole (Karnazes, n.d.). Karnazes ran in 50 marathons in 50 states in 50 days ending up finishing the New York City Marathon in 3 hours (Karnazes, n.d.).

The long walk problem is a multi-stage ultra-endurance event. Assuming 10-12 hrs of walking per day at 4km/h, it would take 14-17 days just to walk based on the total trip time estimate of 168 hrs and 49 min (or 169 hrs). Based on Timeanddate.com's database on sunrise and sunset during November of 2014, one may expect about 10 hrs and 40 min on average of daylight between Phoenix, AZ and Malibu, CA (given the long walk problem also states the weather is always clear, sunny, and no chance of rain or clouds) (Timeanddate, n.d.). Roughly 13 hrs will be dark or semi-dark. With the high temperature of 85 degrees Fahrenheit (F) peaking during the day and dropping to 45 degrees F at night, it will be advantageous for the subject male-X to walk during the night to conserve his hydration status, avoid hypothermia (activity raising body temperature) and hyperthermia (and sunburn).

According to the Federal Emergency Management Agency (FEMA), the average person with average activities in an average temperate climate needs at least 1 gallon of water per day. One gallon of water weights about 8.34 lbs. So rationing 1 gallon of water per day for 14-17 days, the subject male-X (who weighs 154 lbs himself) would need to carry 116.76 to 141.78 lbs of water on the first day of journey according to FEMA estimates. Eight days into the walk, male-X would still be carrying about 50.04 to 75.06 lbs of water. If male-X walked without stopping (24 hrs) and it takes him 7 consecutive days, he would need to carry 58.38 lbs of water. The reasonable conclusion is that male-X will not be able to carry all of his hydration requirements (in addition to the rest of his supplies), and therefore, he will not finish the long walk.

To compare the long walk multi-stage endurance event hydration issues with ultra-endurance athletes, Costa et al. (2013) noted that ultra-endurance runners need to ration water at least 12L/day (or 3.17 gallons/day) to maintain euhydration. During a multi-stage endurance event, it is best to start the day in an euhydrated state (Costa et al., 2013). However, it is difficult for ultra-endurance athletes (e.g. running, cycling, hiking, etc.) to maintain proper hydration not only because of equipment/supplies logistics, but also because of suppressed appetite, race-time nerves, gastric distress, fluid-intake disinterest, and physical stress of the event (Costa et al., 2013). Body mass (BM) losses of greater than (or equal) to 2% due to loss of body water can lead to negative changes in haemorheology, anemia, metabolic function, heat tolerability, and strain on the cardiovascular system (Costa et al., 2013; Dempster, Britton, Murray, & Costa, 2013). However, in a some highly trained elite endurance runners, Costa et al. (2013) noted that the aforementioned 2% BM loss due to loss in fluids did not seem to negatively impact their work production due to elite adaptation.

It is important to include adequate sodium in foods or fluids (700 to 1200 mg/L) to stimulate fluid intake, help glucose and water absorption, maintainence of homeostasis, and avoid hyponatraemia which tends to be riskier amongst slower runners averaging less than 8km/hr (Costa et al., 2013). Geesman et al. (2014) also noted a fluid intake of 300-500ml/hr (10-17 fluid ounces/hr) may be adequate to maintain hydration for ultra-endurance athletes in temperate conditions. That equates to 0.08-0.13 gallons/hr. With 1 gallon of water, one might marginally be able to maintain performance for 8-12.5hrs.

Sufficient macronutrients and their ratios are crucial to maintain a high workload and to mitigate depletion of muscle glycogen and blood glucose levels which are associated with feeling fatigued (Dempster et al., 2013; Geesmann, Mester, & Koehler, 2014). Knechtle's (2013) review found that ultra-endurance athletes consume about 68% of overall energy intake (EI) as carbohydrates, about 19% as fat, and about 12-13% as protein). In Geesman's et al. (2014) study, fat intake of 30 to 40% of overall EI seemed to work well with lesser intensity (40% of VO_{2max}) exercise. Jeukendrup (2013) noted that for high intensity exercise, carbohydrates are the key energy source. For moderate intensity exercise (e.g. long walk), carbohydrate and fat are the body's important fuel sources as the body will rely mostly on carbohydrate and fat oxidative energy systems (Jeukendrup, 2013; Kenny, Wilmore, & Costill, 2012).

Dempster et al. (2013) recommended 10g of carbohydrate (CHO) per kg of BM per day for 4-6 hrs of strenuous activity, and an additional 30-60g CHO per hour spent running. Dempster et al. (2013) also recommended 1.2 to 1.6g of protein (PRO) per kg of BM per day.

Dempster et al. (2013) noted that CHO drink blends (glucose to fructose ratio 2:1) is recommended for exercise bouts in excess of 3hrs to improve exogenous CHO oxidation efficiency, reduce fatigue, and improve performance. Post-exercise bout, Dempster et al. (2013) recommended an additional 1.0-1.5g of CHO per kg BM and at least 0.5g PRO per kg BM to support resynthesis and tissue healing.

Geesmann et al. (2014) noted that the oxidation rate of exogenous CHO increases linearly with increasing exercise intensities until about 50-60% of VO_{2max}. At higher exercise intensities, it is more difficult to absorb CHO in the intestine which leads to the oxidation rate of exogenous CHO plateauing at around 60-90g/hr (Geesman et al., 2014; Jeukendrup, 2014). Carbohydrates can be grouped as rapidly oxidizing (up to around 60 g/hr or 1g/min; glucose, maltose, sucrose, maltodextrin, and amylopectin starch) or slow oxidizing (up to 30g/hr or 0.6g/min; fructose, galactose, isomaltulose, trehalose, and amylose) (Jeukendrup, 2013).

Jeukendrup (2014) noted that current theories believe glucose absorption is attenuated by the sodium-dependent transporter (SGLT1) which reaches saturation at around 60 g/hr. Different carbohydrates metabolize along different paths. For example, fructose absorption relies on GLUT5 which is not sodium-dependent. Jentjens et al. (as cited in Jeukendrup, 2013) studied the absorption of glucose and glucose:fructose mix on a group of cyclists exercising at moderate intensity and found that using the multiple transport exogenous carbohydrate, the 1 g/min oxidation rate barrier could be broken. Jentjens and Jeukendrup (as cited in Jeukendrup, 2013) found that an exogenous glucose:fructose mix ingested at 2.4 g/min yielded 65% higher oxidation rates (peaking at 1.75 g/min) over glucose only. Glucose:fructose far exceeded other tests with glucose:sucrose, maltodextrin:fructose, glucose:maltose, and glucose:sucrose:fructose (Jeukendrup, 2013). Maltodextrin:fructose which is less "sweet tasting" (and therefore more palatable and viable alternative to glucose:fructose) also performed very well with oxidation rates of 1.5g/min when consumed at 1.8g/min (Jeukendrup, 2013).

Maintaining adequate hydration and nutrition is important during any exercise, but especially for the moderately-intense long walk so that the subject male-X may perform his best, maintain workload, and physiologically adapt to the duress.

The long walk is a multi-stage, ultra-endurance, moderate-intensity to lower-high-intensity range, aerobic (as opposed to anaerobic) endeavor. This type of "race" would recruit primarily type I muscle fibers which are suited for aerobic endurance events with their high oxidative capacity and high fatigue resistance (Kenny et al., 2012). However, type I and type IIa fibers are most likely recruited for short hills/ascents during the journey as type IIa fibers are good for shorter bouts of high-intensity (but not as high-intensity as needing the type IIx fibers). Type IIa fibers are moderately fatigue-resistant, have moderately high oxidative capacity and a high glycolytic capacity, and produce greater force/strength (Kenny et al., 2012). On the flats of the long walk, it is lower intensity which type I fibers are suited for. Muscle fibers are recruited in an orderly fashion (type I, type IIa, type IIx) as exercise intensity increases (Kenny et al., 2012). Because male-X will probably have to walk at least 10-12 hr/day, type I muscle fibers will become depleted of their glycogen energy supply first, and as that occurs, type IIa fibers will get recruited to maintain workload (Kenny et al., 2012). As type IIa fibers start to become depleted, more type IIx fibers will be recruited to maintain the same workload (Kenny et al., 2012). That is why endurance-racers experience different stages of fatigue. If male-X is an experienced endurarnce athlete, it is very likely that his lower limbs (for ambulation) have a high percentage of type I fibers (Kenney et al., 2012). It is very likely that his calf muscles (gastrocnemius and soleus) will cramp and feel fatigue (Kenny et al., 2012).

During exercise, the key endocrine glands responsible for maintaining homeostasis are the anterior pituitary gland, thyroid gland, adrenal glands, and pancreas (Kenny et al., 2012). Growth hormone (GH) regulated by the anterior pituitary gland and stimulated during aerobic types of exercise, manages muscle growth/hypertrophy, amino acid transport, and fat metabolism (Kenny et al., 2012). The thyroid gland produces triiodothyronine (T3) and thyroxine (T4) which regulate metabolism/metabolic rate of all tissues, increase protein synthesis, increase size/number of mitochondria, help the absorption of glucose, as well as promote glycolysis, gluconeogenesis, and fat oxidation (Kenny et al., 2012). The adrenal glands produce epinephrine and adrenaline which affect exercise by increasing heart rate and contraction force, metabolism, blood pressure, respiration, and blood to skeletal muscles (Kenny et al., 2012). The pancreas makes insulin (regulates blood sugar) and glucagon (breaks down liver glycogen into glucose for energy) (Kenny et al., 2012).

During the long walk, more blood will be redistributed to the areas that need it the most--lower body for ambulation, and parts of the upper body for carrying the backpack and stabilizing the trunk. The most active areas/muscles may receive up to 80% more blood flow (Kenney et al., 2012; Rehrer, 2001). As the long walk progresses, sweat also increases causing the primary water and electrolyte loss during exercising (Rehrer, 2001).

For the long walk, male-X would ration water to 2.5 gal/day (equivalent to 20.85 lbs water/day). For walking at an intensity of 3.5 METS for 720 minutes (12hrs), the 154 lb male-X would require 2940 Calories. For the other 12 hrs, with activity of 1 METS (approximately), male-X would need 840 Calories. Male-X would need, at minimum without adjust weight for supplies and pack, 3780 Calories. By dropping body mass from 154 to 144 (10 lbs or 6.5%) and with 1 lb = 3500 Calories, that is a loss of 35000 Calories (or a little over 9 days without eating).

Supplies I would carry are: emergency bivy sack to sleep in, water and water bottle, Lifestraw (lightweight straw water filtration), Light My Fire knife/steel firestarter, water proof matches, Petzl headlamp, identification bracelet, Goal Zero portable solar panel and charger (small unit made for backpacking), drink powder (for carbohydrates and electrolytes), pork jerky for protein and fat, backpack, cellphone, 6 yards of 400# military grade kevlar cord, 100 ft of military grade 550 paracord, LED flashlight.

However, due to the hydration issue and weight of water, male-X would maybe carry 2 days worth of water. I would say hydration is the limiting factor. Walking at 4km/h for 10-12 hrs per day, I would cover 25-30 miles per day at best. In 2 days, I would be 50-60 miles away from Phoenix along Interstate Highway 10.

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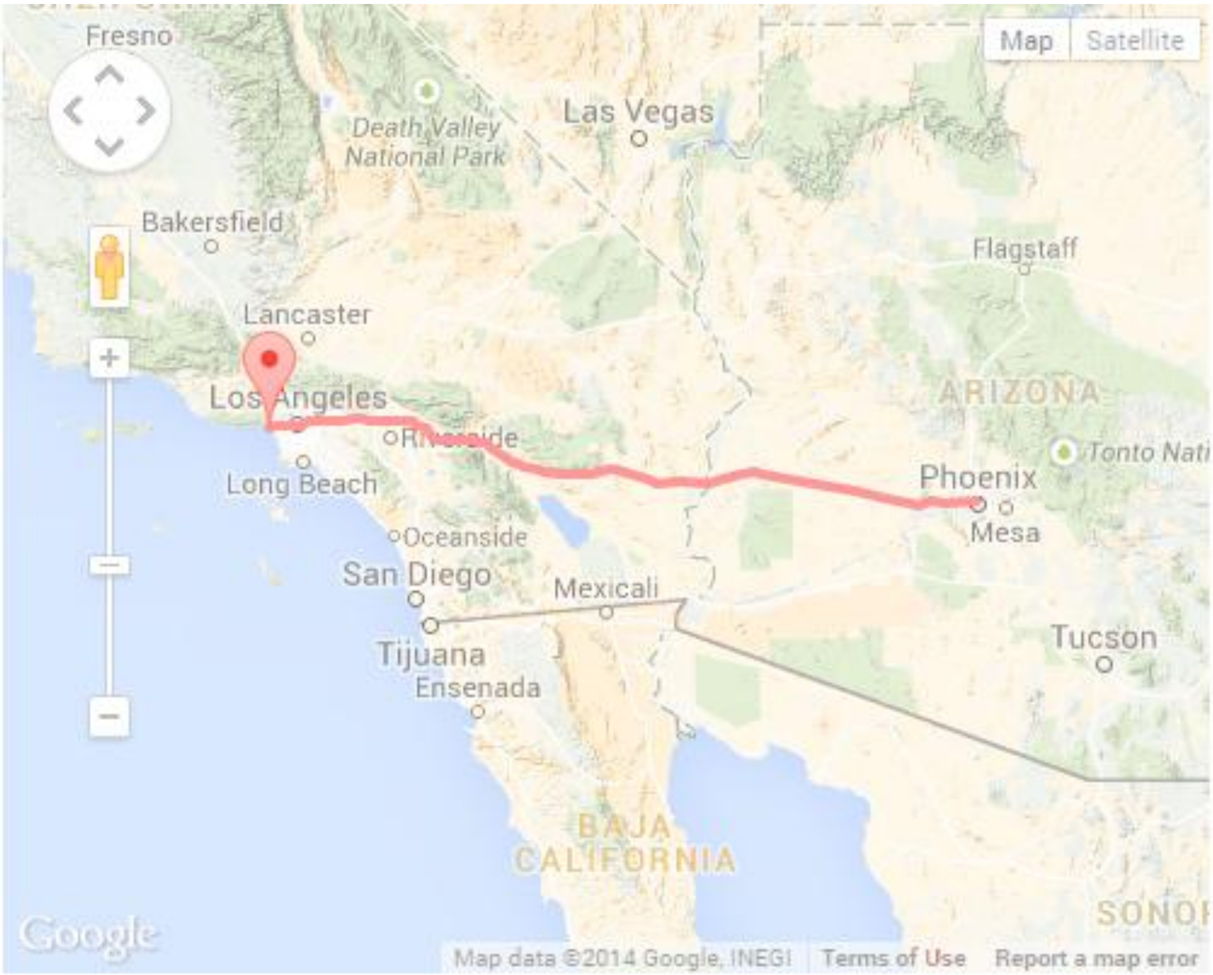
Appendix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Fresno
Death Valley
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Bakersfield
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ARIZONA
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Phoenix
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Oceanside
San Diego
Mexicali
Tijuana
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BAJA
CALIFORNIA
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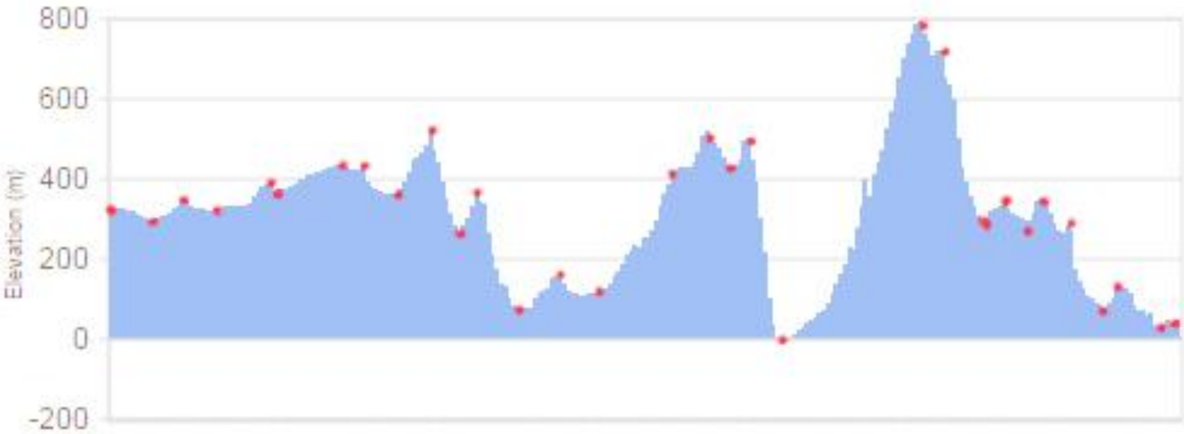
Report a map error


800
600
400
200
0
-200
Elevation (m)

	A	B	C	D
1	CA to Phx, Elevation points(meters)		uphill	downhill
2	329.7			
3	298.1	31.6		31.6
4	348.5	-50.4	50.4	
5	325.6	22.9		22.9
6	394.1	-68.5	68.5	
7	375.1	19		19
8	434.5	-59.4	59.4	
9	364.2	70.3		70.3
10	528	-163.8	163.8	
11	283.2	244.8		244.8
12	362.8	-79.6	79.6	
13	81.6	281.2		281.2
14	159.7	-78.1	78.1	
15	116.8	42.9		42.9
16	415.3	-298.5	298.5	
17	507.3	-92	92	
18	429.6	77.7		77.7
19	504.1	-74.5	74.5	
20	-6.3	510.4		510.4
21	796.8	-803.1	803.1	
22	723.7	73.1		73.1
23	292.9	430.8		430.8
24	343.1	-50.2	50.2	
25	295.2	47.9		47.9
26	344.3	-49.1	49.1	
27	271	73.3		73.3
28	79.9	191.1		191.1
29	135.2	-55.3	55.3	
30	35.3	99.9		99.9
31	47	-11.7	11.7	
32			1934.2	2216.9
33				
34				
35	http://www.mapdevelopers.com/elevation_calculator.php			
36				

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wild walks

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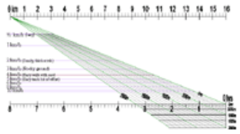
Naismith's Rule (estimate walking time)



Naismith's rule was developed by a William Naismith in 1892 as a basic rule of thumb that can be used to calculate the time it will take to walk from point a to b. The formula has been adapted a little since then and considers the distance to walk, the altitude changed and the speed that you will walk at.

This rule assumes a reasonable level of fitness, but Tranter's corrections can but used to change the time to suit a particular level of fitness.

Naismith's Rule first makes a calculation based on distance over time. eg if your walking a 4km/h for 4 km it will take you one hour. Not rocket science. But it adds a bit over an hour and a half for every 1000m you climb and about three quarters of a hour for every 500 meters you descend.

I have include two methods to help you in your trip planning. Firstly a calculator and secondly a Nomogram that you can use with a ruler in the field. Have a play with both

Naismith's Rule Calculator | Naismith's Rule Nomogram | How to use Naismith's Rule Nomogram

Distance: 655.003 km
Walking Speed: 4 km/h
Total climbing: 1934.2 m
Total Decent: 2216.9 m

Calculate | Clear Fields

Est time = 168 hrs 49 mins

If you wish to apply Tranter's Corrections I have include a table below to help.
Fitness in the left column is the number of minutes that it would take you to climb 1000ft over 800m

Time taken in hours using Naismith's Rule

fitness (m)	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
15 (fit)	1	1½	2	2¾	3½	4½	5½	6¾	7¾	10	12½	14½	17	19½	22	24
20	1¼	2¼	3¼	4½	5½	6½	7¾	8¾	10	12½	15	17½	20	23		
25	1½	3	4¼	5½	7	8½	10	11½	13¼	15	17½					
30	2	3½	5	6¾	8½	10½	12½	14½								
40	2¾	4¼	5¾	7½	9½	11½										
50 (unfit)	3¼	4¾	6½	8½												