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Changes in submaximal and maximal measures of cardio-respiratory fitness resulting from 6-days of mountain walking

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ABSTRACT
Trekking is a popular activity associated with cardiovascular benefits. The aim of the present study was to investigate changes in the submaximal heart rate, oxygen uptake, oxygen pulse, and blood lactate concentration associated with a 6-day mountain walk. Over a 12-year period, 134 male (age 21.0 ± 1.4 years) and 124 female undergraduates (age 20.8 ± 1.6 years) participated. Three days before the trek submaximal and maximal laboratory measures were made on participants walking on a motorized treadmill using a breath-by-breath system to measure oxygen uptake (VO2) during exercise. Oxygen uptake and heart rate were recorded during steady-state exercise at treadmill gradients 0, 4, 8, 12, and 16%. Measurements were made, at the same time of day, two days after the trek. There were significant improvements in both the walking economy and the relative exercise intensity (%VO2max) at submaximal treadmill gradients 0-16%. Post-trek, heart rate was lower while oxygen pulse was higher, at each treadmill gradient. There was a significant increase in the maximal oxygen uptake for men (+2.7%) and women (+2.9%). The results of the present study suggest that improvements in cardiorespiratory fitness are associated with a 6-day mountain walk with no sex difference in the exercise response.

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Mountain walking; men and women; cardiorespiratory fitness; maximum oxygen uptake; trekking

Introduction

Current consumer travel trends support growth in the “pursuit of a healthy life”, which includes walking, wellness and sports tourism (UNWTO, 2019). The most-visited region in terms of global tourism is Europe with millions of people engaged in exercise of moderate intensity (e.g., hiking) for health and fitness (Burtscher et al., 2005).

Central to health is the assumption that the majority of a given population will incorporate physical activity into their overall “lifestyle”. Over the years, there has been a rise in unstructured, “Green Exercise” (exercise, whilst at the same time being exposed to nature) – which has been associated with a wide range of health benefits (Thomsen et al., 2018). Green exercise (e.g., mountain walking) is also a way to establish lifestyle changes emphasizing greater levels of physical activity (Huber et al., 2022). Along parallel lines in the United Kingdom there has been a call to establish an NHS (National Health Service) career pathway of exercise specialists to support sustainable referral pathways (promotion of physical activity for population health; Saxton, 2022).

As early as 2005 Pretty et al. showed that green exercise was more effective than exercise alone in decreasing blood pressure and improving mood – as an index of mental health. The restorative effects of nature was also historically evident in post-operative patients who could look out onto a natural scene versus a brick wall outside their hospital window. Those patients randomly assigned to view a natural scene (trees and shrubs) had a shorter postoperative hospital stay and needed less potent analgesics compared with a similar group of patients who did not have access to a natural scene (Ulrich, 1984). A recent study that looked at changes in salivary cortisol concentrations, as an index of the acute physiological stress response to a 3-h mountain walk versus a sedentary control condition, concluded that there was a significant lowering of salivary cortisol concentration (Niedermeier et al., 2017a), which was taken as a positive outcome. Niedermeier et al. (2017b) also studied the psychological aspects of mountain walking – namely the “affect” (an emotional response to a situation) of physical activity of greater than 45 minutes duration in adults aged 18 to 70 years of age. Niedermeier et al. (2017b) demonstrated that a 3-h outdoor mountain hike (Innsbruck, Austria) showed significantly greater positive effects on affective valence (“attractiveness” or “goodness”), activation and fatigue compared with an indoor treadmill walk which simulated the outdoor hike in terms of distance, elevation and duration.

The physiological responses/energetics of backpackers (fully independent mountain walkers/trekkers) elicit an exercise intensity of about 60–77% maximum heart rate (DeVoe & Dallack, 2001). In fitter participants, the relative exercise intensity was lower (50–65% HRmax; Hill et al., 2008). Overall hiking at self-selected walking speeds reflects a moderate exercise intensity (approximately 60% HRmax), confirmed by parallel telemetric measures of oxygen uptake, determined during a circuit of the Grand Canyon (Sperlich, 2010).

In addition Kang (2014), in a study that recruited older (~60 years of age), obese women (~35% body fat) demonstrated that the use of trekking paths (“green” exercise), in an urban environment could result in physiological changes.

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Namely, a significant loss in body mass, lowered systolic blood pressure, and increased muscular endurance in this population. Despite earlier studies demonstrating the positive physiological, metabolic and psychological benefits of mountain walking, relatively little is known about the more popular activity of hut-to-hut trekking, which the present study sought to address.

Methods

Data collection in the laboratory

Between the years 2008–2019 two hundred and fifty-eight students ($n = 134$, men; $n = 124$, women), studying Sport and Exercise Science at Oxford Brookes University (United Kingdom) participated in "Le Tour du Mont Blanc" (TMB) at a frequency of approximately 20–24 students per year. The pre-trek physical characteristics of the men were: age 21.0 ± 1.4 years; height 1.80 ± 0.08 m; body mass 78.7 ± 11.3 kg, and of the women were: age 20.8 ± 1.6 years; height 1.67 ± 0.06 m; body mass 63.5 ± 10.3 kg. During three days preceding the trip to the Alps, participants reported to the laboratory in a euhydrated state for anthropometric measures and submaximal and maximal exercise testing. Stature (Holtain, Crymych, Wales; wall-mounted stadiometer) and body mass (Seca weigh scales, 875; Birmingham, United Kingdom) together with anthropometric measures were made under standard laboratory conditions.

Walking economy (VO_2; ml kg^{-1} min^{-1}) was measured during submaximal treadmill exercise (Woodway, Model PPS 55) to derive individual oxygen uptake (VO_2) versus heart rate regression equations. Oxygen uptake and carbon dioxide production (VCO_2) were measured breath-by-breath using a Cortex Metalyzer (Leipzig, Germany). Exercise heart rate was measured continuously using radio-telemetry (Polar technology, Kempele, Finland). The treadmill speed was set at 1.5 m s^{-1} (3.3 mph) and remained at this speed for the duration of the test. The initial gradient (0%) was maintained for 4 minutes and at the end of this and each subsequent four-minute period the gradient was increased by 4% (to 4%, 8%, 12% and 16% respectively). During minutes 3–4 at each gradient a rating of perceived exertion (RPE) value was recorded (6–20 scale; Borg, 1982) and a blood sample was obtained by finger-stick to determine the blood lactate concentration (Biosen; EKF Diagnostics, Cardiff, UK). After a short, period of passive recovery (10 minutes) participants performed a test to determine the maximum oxygen uptake (VO_2max) using a modified protocol (Balke & Ware, 1959). In the latter test, the treadmill speed remained at 1.5 m s^{-1} while the treadmill gradient increased 2% every minute until 20%. Thereafter, the treadmill speed increased 0.13 m s^{-1} (0.3 mph) every minute until volitional exhaustion.

Data collection in the field

The route of the Tour du Mont Blanc is approximately 150 km long and took a total of 7-days to complete, starting and finishing in the small town of Les Houches (near Chamonix, France). The seventh (last) day was not a typical "mountain" day as the route simply descended the Chamonix Valley from Le Tour to Les Houches and so any data from this day was excluded from the final analysis (Table A1 and Figure A1). During each day's trek participants wore a Polar heart rate monitor and recordedany stops on the route (e.g., lunch), so that only the walking heart rate was recorded. Because each participant had their own unique regression equation linking heart rate and oxygen uptake (data collection in the laboratory) it meant that exercise intensity during trekking could be assessed as either the percentage maximum oxygen uptake (%VO_2max) and or the percentage maximum heart rate (% HRmax).

The study received University Ethical Approval and all participants were treated in accordance with the principles laid down in the Declaration of Helsinki (2001). Not all participants completed all aspects of data collection (laboratory and field) due to illness, injury or fatigue. Where an individual could not participate in the post-test data collection their results were not included in the final analysis (only paired data was used for analysis). Two-way mixed ANOVAs were conducted using SPSS (SPSS Ltd., Chicago, Version 27) followed by a *post hoc* Bonferroni correction to investigate the influence of sex on submaximal and maximal measures during mountain walking. An Eta-squared Effect Size ($Ŋp^2$) was adopted with the ANOVA where $Ŋp^2 = 0.01$ indicates a small effect; $\eta^2 = 0.06$ indicates a medium effect; $\eta^2 = 0.14$ indicates a large effect. Whenever the assumption of sphericity was violated, the Greenhouse–Geisser correction was used. Differences between men and women were analysed using an independent samples t-test with an alpha set at $p < 0.05$. Pre- versus post-values were analysed using a dependent samples t-test with an alpha set at $p < 0.05$.

Results

Responses to mountain walking

The average trekking heart rate ranged from 120 ± 12 (men) and 128 ± 13 b min^{-1} (women) (Day 5) to 133 ± 13 (men) and 144 ± 15 b min^{-1} (women) (Day 1) with the men recording a significantly lower daily heart rate compared with the women ($p < 0.001$). Overall the daily trekking relative exercise intensity was higher for the women compared with the men either as the %VO_2max (men, 46.3 ± 9.4; women 52.2 ± 12.5) or as the % HRmax (men, 64.2 ± 6.2; women 69.2 ± 6.2) ($p < 0.001$) (mean values for the six days of mountain walking). Individual heart rates ranged from ≤110 (level walking) to ≥190 b min^{-1} during strenuous sustained gradients (e.g., ascent to Col de la Seigne at 2,516-altitude metres above sea level).

Responses to maximal exercise

As a result of the 6-day mountain walk the maximum aerobic power (VO_2max) increased in both men (pre- 52.2 ± 6.8 vs. post- 53.6 ± 6.1) and women (pre- 42.9 ± 5.7 vs. post- 44.2 ± 5.4 ml kg^{-1} min^{-1}) ($p < 0.001$). This was accompanied by a significant increase in the treadmill time to exhaustion for men (pre-1019 ± 126 vs. post-1086 ± 170 s) and women (pre-835 ± 101 vs. post-872 ± 102 s) ($P < 0.001$). The maximum heart rate declined slightly for men (pre-197 ± 8 vs. post-196 ± 8 b min^{-1}) with women showing little change; (pre-196 ± 8 vs.

post-196 ± 7 b min^{-1}), overall there was a significant lowering of the maximum heart rate post-trek ($p < 0.001$).

Responses to submaximal exercise

In the present study, walking economy was defined as the oxygen uptake (VO_2) at each treadmill gradient during the submaximal treadmill test. All post-trek VO_2 values for walking economy were significantly lower compared with pre-trek values (Table 1). There was no main effect for sex F(1, 162) = 0.31, $p < 0.581$, Ŋp^2 = 0.002, there was a significant interaction between sex and oxygen uptake F(3.10, 502.34) = 3.44, $p < 0.016$, Ŋp^2 = 0.021.

The relative exercise intensity (%VO_2max) was lower at each treadmill gradient (0% to 16%) after compared with before the 6-day mountain walk (0%, 33.5 ± 6.4 vs. 30.9 ± 5.6; 4%, 40.0 ± 7.1 vs. 37.6 ± 6.9; 8%, 50.6 ± 9.0 vs. 48.0 ± 8.7; 12%, 62.7 ± 11.0 vs. 59.7 ± 10.0 and 16%, 73.5 ± 12.2 vs. 70.9 ± 11.3%VO_2max) ($p < 0.001$).

There was a main effect for the blood lactate concentration (BLa) F(3.55, 638.90) = 153.88, $p < 0.001$, Ŋp^2 = 0.461. There was no significant effect for sex F(1, 180) = 2.38, $p = 0.125$, Ŋp^2 = 0.013. There was a significant interaction between sex and gradient uptake F(3.55, 638.90) = 7.37, $p < 0.001$, Ŋp^2 = 0.039 There was no difference pre- versus post-trek in the blood lactate response (Table 4).

There was a main effect for the rating of perceived exertion (RPE) on gradient F(4.53, 902.13) = 132.62, $p < 0.001$, Ŋp^2 = 0.868. There was a significant effect for sex F(1, 199) = 21.07, $p < 0.001$, Ŋp^2 = 0.096. There was a significant interaction between sex and RPE F(4.53, 902.13) = 6.04, $p < 0.001$, Ŋp^2 = 0.029. There was a significant difference in the RPE pre- versus post-trek at 0 (men, 7.4 ± 1.2 vs. 7.0 ± 1.0; women, 7.6 ± 1.3 vs. 7.5 ± 1.3) 4 (men, 8.9 ± 1.6 vs. 8.3 ± 1.3; women, 9.2 ± 1.6 vs. 8.8 ± 1.5) and 16% gradients (men, 14.0 ± 1.7 vs. 13.3 ± 1.4; women, 15.0 ± 1.9 vs. 14.6 ± 1.8) ($p < 0.001$) there was no significant difference at 8 (men, 10.6 ± 1.5 vs. 9.9 ± 1.6; women, 11.3 ± 1.5 vs. 12.9 ± 1.5) and 12% (men, 12.4 ± 1.5 vs. 11.8 ± 1.5; women, 13.1 ± 1.5 vs. 12.9 ± 1.5) treadmill gradients.

Discussion

A six-day mountain trek produced significant increases in cardiorespiratory fitness among young men and women. Benefits seen during the submaximal treadmill exercise included an improved walking economy, lowered heart rate and rating of perceived exertion (RPE), and an increased oxygen pulse. Maximal exercise responses that improved included VO_2max and time to exhaustion. Despite the fact that the women consistently walked at a significantly higher relative exercise intensity compared with the men, they did not show any greater improvements compared with the men in any of the measures.

Although there have been previous studies investigating the effects of mountain walking (e.g., Ainslie et al., 2002a, 2002b), none have been directly compared with the current study in terms of experimental design, exercise duration, or measures undertaken. For this reason, it is worth making a comparison with laboratory-based studies of similar or longer overall duration. The daily exercise duration in the current study ranged from 5 to 8 hours, notably longer than most laboratory-based interventions. However, the exercise intensity was distinctly lower than that seen in many studies at 52.2% and 46.3%VO_2 max for women and men, respectively. For example, there have been week-long training studies using cycle ergometry at a training intensity of 60–65%VO_2max which have shown increases in VO_2max of 3.0 (Putman et al., 1998) and 8.3% (Convertino, 1983) among healthy college-aged men. The former study reported a 3% incresae in *VO2*max similar to that found in the present study, respectively. A longer (6-week) endurance running intervention reported by Ramsbottom et al. (1989) resulted in an increase in VO_2max of 8.3% for training compared with a control group. In a similarly designed study, Astorino et al. (2012) reported a 6.4 and a 5.9% increase in VO_2max and oxygen pulse, respectively, with high-intensity interval training.

As well as producing improvements in maximal exercise performance, the 6-day walking intervention adopted in the present study also produced significant changes in submaximal exercise responses, indicative of improvements in cardiorespiratory fitness. The walking economy improved, meaning the participants used significantly less oxygen at each of the treadmill gradients after the trek than they had prior to the trek (Table 1). Similarly, and in keeping with this observation, the %VO_2max elicited at each treadmill gradient was also significantly lower after, compared with before the trek, indicating that there was a reduction in physiological stress at the same walking speed/gradient as a result of the intervention. This was reflected in the lower scores recorded for the rating of perceived exertion (RPE) after compared with before the walk.

Rather surprisingly, given the consistent picture exhibited by other fitness indicators, the blood lactate responses were not indicative of improved fitness, There were no significant differences between the pre- and post-trek blood lactate values at any of the treadmill gradients (Table 4). This contrasts with many earlier training studies. For example,

Table 1. Submaximal oxygen uptake values (VO_2) before and after a 6-day mountain walk (mean ± SD).

	Men		Women	
Treadmill gradient (%)	Pre-VO_2 (ml kg^{-1} min^{-1})	Post-VO_2 (ml kg^{-1} min^{-1})	Pre-VO_2 (ml kg^{-1} min^{-1})	Post-VO_2 (ml kg^{-1} min^{-1})
0	15.6 ± 1.9	14.9 ± 1.8*	15.7 ± 1.8	15.1 ± 1.8*
4	18.8 ± 2.2	18.0 ± 2.1*	18.9 ± 2.3	18.5 ± 2.1*
8	23.9 ± 2.7	22.9 ± 2.7*	23.7 ± 2.9	23.5 ± 2.4*
12	29.6 ± 2.9	28.6 ± 3.0*	29.3 ± 3.3	29.4 ± 2.9*
16	35.4 ± 4.5	34.3 ± 3.3*	34.8 ± 4.5	35.0 ± 3.3*

*significant difference between pre- and post-trek VO_2 values ($p < 0.001$).

Table 2. Heart rate (HR; b min^{-1}) response during submaximal treadmill exercise before and after a 6-day mountain walk (mean ± SD).

	Men		Women	
Treadmill gradient (%)	Pre-HR (b min^{-1})	Post – HR (b min^{-1})	Pre – HR (b min^{-1})	Post – HR (b min^{-1})
0	102 ± 13	94 ± 11*	112 ± 15	106 ± 12*
4	110 ± 13	102 ± 11*	122 ± 14	118 ± 11*
8	124 ± 14	116 ± 11*	140 ± 15	135 ± 14*
12	142 ± 16	132 ± 13*	160 ± 15	155 ± 14*
16	160 ± 17	151 ± 14*	177 ± 14	173 ± 13*

*significant difference between pre- versus post-trek for the submaximal heart rate response ($p < 0.001$).

Table 3. Oxygen pulse (ml kg^{-1} beat^{-1}) during submaximal exercise before and after a 6-day mountain walk (mean ± SD).

	Men		Women	
Treadmill gradient (%)	Pre-O_2 pulse (ml kg^{-1} b^{-1})	Post-O_2 pulse (ml kg^{-1} b^{-1})	Pre-O_2 pulse (ml kg^{-1} b^{-1})	Post-O_2 pulse (ml kg^{-1} b^{-1})
0	0.15 ± 0.02	0.16 ± 4.2*	0.14 ± 0.02	0.14 ± 0.04*
4	0.17 ± 0.02	0.17 ± 0.02*	0.15 ± 0.02	0.16 ± 0.02*
8	0.19 ± 0.02	0.20 ± 0.03*	0.17 ± 0.02	0.18 ± 0.02*
12	0.21 ± 0.03	0.22 ± 0.03*	0.18 ± 0.02	0.19 ± 0.02*
16	0.22 ± 0.03	0.23 ± 0.03*	0.20 ± 0.02	0.20 ± 0.02*

*significant difference in the submaximal exercise pre- versus post-values for oxygen pulse for both men and women (Table 3).

Table 4. Blood lactate concentration (BLa) during submaximal exercise before and after a 6-day mountain walk (mean ± SD).

	Men		Women	
Treadmill gradient (%)	Pre-BLa (mmol l^{-1})	Post-BLa (mmol l^{-1})	Pre-BLa (mmol l^{-1})	Post-BLa (mmol l^{-1})
0	1.61 ± 0.71	1.73 ± 1.0	1.77 ± 0.79	1.73 ± 0.76
4	1.36 ± 0.79	1.44 ± 0.89	1.37 ± 0.69	1.34 ± 0.74
8	1.59 ± 0.84	1.58 ± 0.88	1.47 ± 0.72	1.60 ± 0.86
12	1.94 ± 0.88	2.01 ± 1.13	2.08 ± 0.98	2.19 ± 1.16
16	2.95 ± 1.36	2.81 ± 1.40	3.69 ± 1.63	3.53 ± 1.76

Putman et al. (1998) undertook a week-long study using cycle ergometry (2 h d^{-1} at 60% VO_2peak) which showed a shift to the right for a plot of blood lactate versus %VO_2 max which, the authors suggested, was the result of a training-induced increase in the proportion of energy derived from oxidative phosphorylation. A 6-week endurance training study demonstrated a 9.8% and 6.6% increase in running speed at reference blood lactate concentrations of 2.0 and 4.0 mmol l,$^{-1}$ respectively. The same study showed lowered RER values at four submaximal treadmill speeds after the training intervention (Ramsbottom et al., 1989), indicative of greater aerobic catabolism of substrate to support energy metabolism. In contrast, the present study did not demonstrate any metabolic changes, possibly due to the short intervention period coupled with the overall low-moderate exercise intensity.

There was a significant lowering of heart rate at each work rate after 6-days of walking (Table 2), consistent with well-established observations on endurance training (e.g., Scheuer & Tipton, 1977). This reduction in exercise heart rate was also seen when plasma volume was expanded exogenously by infusion of a plasma volume expanding solution (Roy et al., 2000) or when hypervolemia, resulting from endurance training occurs (Convertino, 1991). This training-induced increase in body water elevates blood volume leading to an increase in cardiac stroke volume. This, in turn, results in a lower heart rate for a given cardiac output while also enabling higher sweat rates (Convertino, 1983), thus aiding temperature regulation. The observed improvement in cardiac efficiency parallels the increase in oxygen pulse (ml VO_2 kg^{-1} beat^{-1}) seen following the 6-day mountain walk (Table 4).

In conclusion, the present study was notable for the large number of participants given the nature of the exercise intervention. It involved 6-days of mountain walking, which resulted in a significant, though modest, increase in the maximal aerobic power. There was also convincing evidence of enhanced submaximal exercise performance including improvements in walking economy and measures of cardio-respiratory efficiency such as the oxygen pulse. These improvements resulted in a significant reduction in the perceived stress of exercise at given submaximal intensities leading to reduced ratings of perceived exertion post-trek. Measures signalling metabolic adaptations to endurance training such as reductions in the RER values and blood lactate concentration, however, were not observed. The patterns of response to a 6-day mountain trek were similar in both men and women.

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RR and RFTK devised the module. PG devised a spreadsheet to record laboratory and field data. RR, RFTK and MM collected andanalyzedd laboratory and field data and wrote the manuscript. The authors recognize the expertise of R. Varnham in later modifying the original spreadsheet for ease of use by participants. The authors have no conflict of interest.

Disclosure statement

The authors report there are no competing interests to declare. RR and RFTK devised the module. PG devised a spreadsheet to record laboratory and field data. RR, RFTK and MM collected and analyzed laboratory and field data and wrote the manuscript. The authors recognize the expertise of R. Varnham in later modifying the original spreadsheet for ease of use by participants.

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Appendix

Table A1. Daily route of “Le Tour du Mont Blanc” followed by participants of the present study (Itinerary, 2019) for a 6-day mountain walk (mean and SD; distance, gross and net elevation).

*Day: Route	Distance (m)	Gross elevation gain (m)	Net elevation gain/loss (m)	Daytime temperature (^{0}C)
Les Houches to Camping Les Pontets (France)	20,425	1433	+200	11.7–16.2
Camping Les Pontets to Refuge Les Mottets	21,350	1380	+450	6.0–10.9
Refuge Les Mottets to Refuge Maison Vielle (Italy)	18,625	902	−310	4.0–19.0
Refuge Maison Vielle to Refuge Elena	21,750	1521	+197	7.0–15.0
Refuge Elena to Champex (Switzerland)	24,025	896	−591	8.0–23.0
Champex to Le Tour (France)	22,150	1584	−18	20–26
*Le Tour to Les Houches	21,275	0	−473	18.0

*Route data from 2019. Distance on day 7, Le Tour to Les Houches, was not assessed in terms of the walking energy expenditure. Day 7 was a walk down the Chamonix Valley to overnight accommodation and did not represent a typical walking day in the mountains.

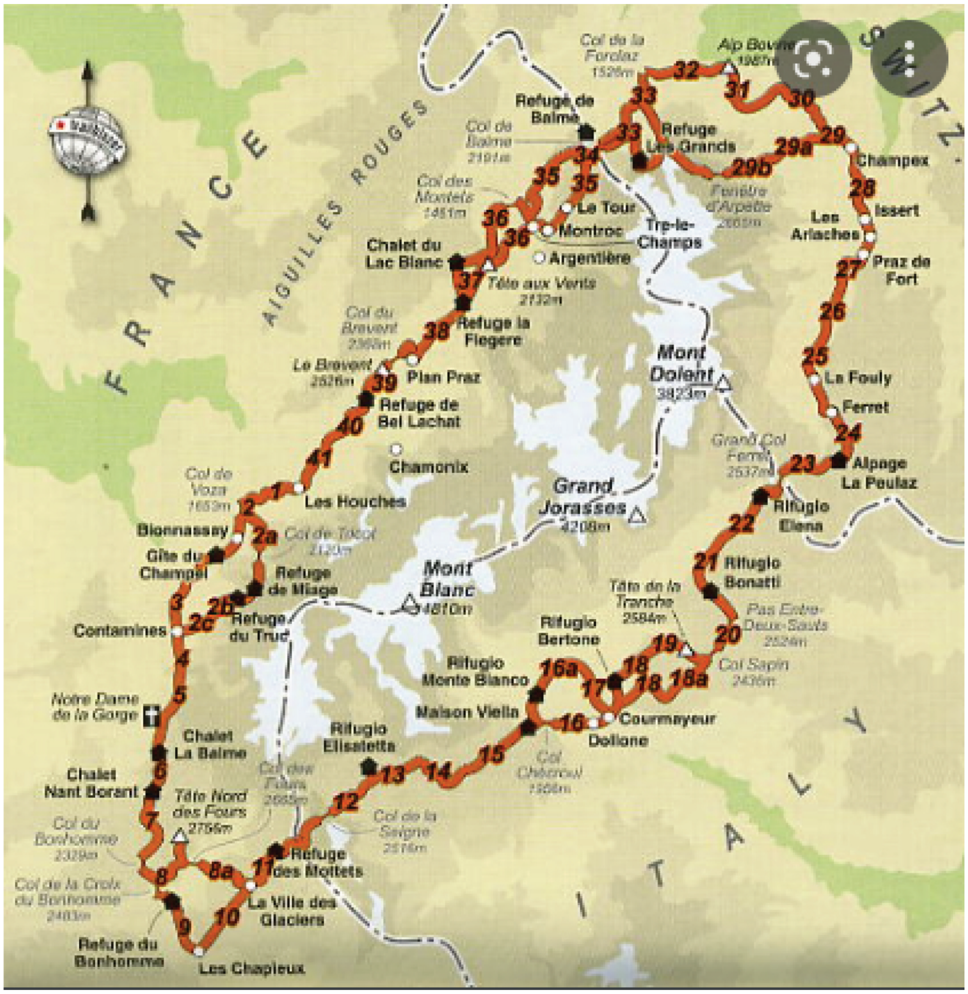

Figure A1. Outline map of “Le Tour du Mont Blanc” with the start and finish point in the village of Les Houches (Chamonix Mont Blanc).