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ORIGINAL RESEARCH

The Epidemiology and Medical Morbidity of Long-Distance Backpackers on the John Muir Trail in the Sierra Nevada

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Introduction—The baseline characteristics and medical morbidity of hikers on the 354 km (220 mi) John Muir Trail (JMT) have not been previously reported.

Methods—Using online and on-site recruitment, hikers completing the JMT in 2014 were directed to an online 83-question survey. Pearson correlations, regression models, and descriptive statistics were applied to data, reported as mean±SD (range). Statistical significance was set at $P<0.05$.

Results—Of 771 respondents, 57% were men aged 43±14 (13–76) y; they hiked 15.2±7.6 (5–34) days and traveled 272±129 (45–1207) km (169±80 [28–750] mi). Backpackers lost 3.5±2.6 (+3.6 to −18.2) kg (7.7±5.8 [+8 to −40] lbs). Over half (57%) of respondents reported illness or injury, with blisters (57%), sleep problems (57%), and pack strap pain (46%) most prevalent. Altitude illness affected 37%. Thirty hikers left the trail; of these, 4 required emergency medical services evacuations (3 by helicopter). Increasing age, base pack weight, and body mass index (BMI) were all associated with a decrease in the distance hiked per day. Higher base pack weight was associated with illness or injury, whereas older age was slightly protective. Increasing BMI was associated with a slight increase in medical illness or injury and a strong association with evacuation from the trail.

Conclusions—JMT hikers experienced medical issues seen on other national trails. Weight loss was prevalent. Most hikers had medical complaints, with few seeking medical attention. Heavy packs and higher BMIs were associated with undesirable outcomes, while older hikers fared better.

Keywords: backpacker injuries, wilderness recreation, lightweight backpacking, altitude illness, base pack weight, backcountry evacuation

Introduction

The John Muir Trail (JMT) is a wilderness hiking trail in the southern Sierra Nevada range in Central California that stretches from a northern terminus, Happy Isles Trailhead in Yosemite National Park, to a southern terminus on the summit of Mount Whitney in Sequoia National Park. The trail, over 321 km (200 mi) and uninterrupted by roads, runs mostly at elevations at or above 2400 m (8000 ft), with 35% of the trail traversing elevations above 3000 m (10,000 ft).

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Cross-sectional surveys have been done to identify illness and injury among long-distance backpackers of the 3540 km (2200 mi) Appalachian Trail (AT)[1,2] coursing along the eastern United States from Maine to Georgia and the 435 km (270 mi) Long Trail in Vermont.[3] There are no similar data available for the 354 km (220 mi) JMT in Central California.

Backpacking has changed in the last decade with the availability of lighter materials. Backpackers debate whether lightweight or traditional backpackers are more exposed to illness and injury. There is little data to support either argument. Pack weights are compared by generally accepted base pack weight (BPW) categories of heavy, traditional, lightweight, ultralight, or super-ultralight. These refer to the total weight of the entire gear kit, excluding consumables (food and water). Consumables are not included because the amount varies by trip length and conditions. The authors are aware of only 1 small study addressing the impact of pack weight

on illness and injury; that study concluded that increasing pack weight was correlated with increased incidence of paresthesias.[4]

During the trip, medical conditions were experienced by 50 to 80% of long-distance hikers, depending on the source citation.[1–3] Medical assistance was sought up to 25% of the time; however, activation of emergency medical services (EMS) was uncommon.[2] Only 8.4% of long-distance hikers reported feeling unprepared to deal with illness and frequently self-managed problems on the trail.[3] A review of the United States National Park System from 2007 to 2011 reported that the national incidence of EMS events was 45.9 events per 1 million visitors.[5] A backcountry survey of trail users is well suited to investigate events that affect hikers but do not rise to the level of EMS activation.

In this study we profile the epidemiology, conditioning level, pack weights, speed of travel, and prevalence of illness or injury or evacuation during hiking experiences. We propose that conditioning, lightweight BPW, and faster rates of travel correlate with an increased likelihood of trip completion without evacuation and decreased prevalence of illness and injury.

Methods

A retired San Francisco lawyer who is a JMT enthusiast wrote the survey using Survey Monkey. Two of the authors of this study (SS, AH) became aware of the survey when recruited to participate in 2014. Survey questions were designed to address concerns often posed by new hikers of the JMT in online communities. Colloquial language is used throughout and is quoted where applicable. The 2014 posthike survey was 60 pages long with 83 questions. Not all questions would be seen by an individual participant, due to the branching response options available regarding the route used by the respondent. Consent for participation in the survey, and the intended distribution of deidentified results, was given on the first page of the survey. A sample of the survey can be seen in Figure 1.

The survey appeared in 2013, with a limited response rate. Recruitment for the survey was performed through online message boards via Yahoo and Facebook groups for prospective JMT hikers. In 2014 on-site solicitation of hikers completing the JMT, with manual distribution of the online address for the survey, was performed by volunteers affiliated with the online hiking communities.

This study is a cross-sectional sample of hikers who completed part or all of the JMT during 2014. The study period was May 7, 2014 through October 19, 2014. The exclusion criteria were hikers who 1) reported a planned trip length of 5 days or less; 2) planned a trip that did not include the JMT; and 3) indicated that they would not answer the questions from a personal, as opposed to a group, point of view. Participation in the survey was voluntary; respondents were not required to answer all 83 questions.

Information extracted from the survey included overall travel time, total distance completed, pretrip estimation of distance per day, actual distance per day, BPW, backpacking experience in the preceding 10 years, prehike physical conditioning, body weight change, difficulty of hike, and prevalence of illness or injury and/or evacuation. A nonvalidated (0–5) scale for severity was used for medical illness and injury questions (Figure 1): 0 denoted "not at all," 1 was "minimal," 3 was "significant," 5 was "severe," and "not applicable or prefer not to answer" was the final answer option. Data are reported in both metric and imperial units. However, the reader should be aware BPW categorizations are colloquially defined by imperial unit cutoffs; thus, the metric conversions create awkward thresholds.

Some survey responses were changed to binary variables for regression analysis. Illness and injury were either present or absent. Prehike physical fitness was either conditioned or not. Conditioning was defined to ascertain prehike preparation for the physical demands of an extended hike at elevation carrying a full pack. The survey categories were <1, 1–2, 2–4, 4–8, 8–16, and >16 hours of exercise per week in the month preceding the hike. We used the survey categories of 4 or more hours to denote prehike conditioning. These categories exceed the minimum recommendation of 2.5 hours of weekly exercise to maintain health.[6]

SPSS Statistics was used to calculate descriptive statistics. Pearson's correlations and logistic regression models were used to compare baseline characteristics with evacuation and reported morbidity. Statistical significance was accepted at $P<0.05$. Data are presented as mean±SD (range) or (P value, 95% CI range) as appropriate. Percentages were calculated from the number of valid responses entered for each query, not for the entire cohort taking the survey. The absence of a response was not considered as a valid entry. In each case in which a percentage is given, the number of persons giving each response will be listed in parentheses. This study received Institutional Review Board review and approval from the University of California San Francisco Fresno Medical Education Program.

Results

DEMOGRAPHICS

Of a total of 771 respondents, the vast majority (93%) completed ≥90% of survey questions (reached or

John Muir Trail Hiker Survey 2014

Did you personally have any of these problems?

	0 - Not at all	1 - Minimal	2	3 - Significant	4	5 - Severe	N/A or prefer not to answer
Pre-existing illness or injury (Please describe in Comments)							
Altitude sickness (symptoms of headache, edema, low energy, mental confusion, clumsiness shortly after getting to elevation - do not use this merely because you felt short of breath on climbs)							
Hypothermia (stumbling, forgetful, or extremely tired and drowsy)							
Excessive shortness of breath (badly "winded") on climbs							
Excessive fatigue or hard to complete necessary daily miles							
Headache							
Sleep problems							
Blisters							
Fall or other trauma on the trip (Please describe in Comments)							
Fracture (Please describe in Comments)							
Muscle strain (pulled muscle) or shin splints							
Diarrhea							
Constipation							
Packstrap or hipbelt pain							
Other chafing or rashes							
Back or hip pain							
Heel or Achilles tendon pain							
Knee or ankle issues							
Muscle cramps							
Respiratory problems (asthma, etc.)							
Heat stroke or heat rash							
Skin infection							
Other illness starting on the trip (Please describe in Comments)							

(Optional) Comments or elaboration

Figure 1. Sample page of the 2014 John Muir Trail Survey.

surpassed question number 75 of 83 numbered questions). Baseline demographics are seen in Table 1. Women comprised 38% (n=281) of respondents; 57% (n=420) were men, and 5% (n=36) checked a box declining to state their sex. Sex was not predictive of occurrences of illness, injury, or evacuation. Age was 43 ±14 (13–76) years. Increasing age ($P<0.001$, 95% CI 0.965–0.988) was protective against the prevalence of medical comorbidity. Prehike body weight was 76±15 (45–145) kg (167±34 [100–320] lbs). During their trip, participants lost −3.5±2.6 (+3.6 to −18.2) kg (−7.7±5.8 [+8 to −40] lbs) with a body mass index (BMI) drop of

Table 1. Hiker demographics

Characteristic	% or *Mean±SD*
Sex (% total)	
Male	420 (57)
Female	281 (38)
Declined to state	36 (4.9)
Age (y)	43±13.8
Height in cm (in)	174.2±9.7 (68.6±3.8)
Starting weight in kg (lbs)	76±15.5 (167.5±34.1)
Ending weight in kg (lbs)	72.5±14.5 (159.9±32)
Pack weight in kg (lbs)	17.6±4.6 (38.9±10.1)
Total distance hiked in km (mi)	277.8±125.4 (172.6±77.9)

$-1.1 kg \cdot m^2 \pm 0.8$ (−1.1 to −5.2). Eleven percent (n=75) had no weight change, and 1.1% (n=9) gained weight. Increasing BMI increased the likelihood of illness or injury and evacuation (P=0.021, 95% CI 1.008–1.096).

TYPES OF BACKPACKERS (FITNESS, EXPERIENCE, RATE OF TRAVEL, BASE PACK WEIGHTS)

The majority of backpackers (73%) reported 4 hours or more of vigorous exercise per week in the month preceding their hike; of these, two thirds rated the difficulty of the hike as "somewhat," "minimally," or "not at all difficult." Of the remaining individuals who completed less than 4 hours per week of prehike training, greater than 50% rated the trip as "fairly," "very," or "felt like a death march" difficulty (Figure 2). The least common exercise amount, <1 hour per week, had 3.6% (n=28) of respondents. Three quarters of individuals

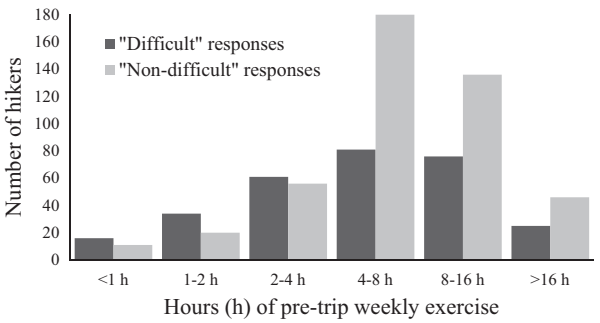

Figure 2. Perceived difficulty of John Muir Trail hike. Categorical prehike conditioning as it relates to perceived effort required to complete the hike. Of those endorsing less than 4 h per week of prehike training, most rated the trip as difficult ("fairly," "very," or "death march" on the survey). Exercising more than 4 hours weekly prehike reduced the difficult responses to <30%, with most rating the trip as "somewhat," "minimally," or "not at all difficult."

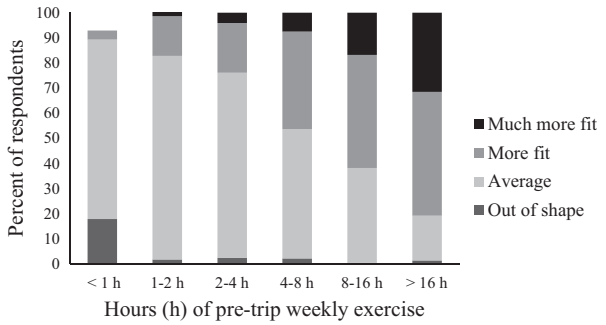

Figure 3. Self-assessment of fitness vs hours of hard activity per week prior to John Muir Trail trip. Percentage of respondents in each fitness category who self-assessed their fitness level as out of shape, average, more fit, or much more fit than age-matched peers.

with <1 h of weekly exercise reported they were of "average fitness." More than 16 hours of weekly exercise before the trip was practiced by 10% (n=73). Of the maximal duration of exercise category, 80% identified as either "more fit" or "much more fit than average" (Figure 3). Conditioning had no predictive relationship with medical illness, injury, or evacuation.

Those with no prior backpacking activity were a small minority at 3.9% (n=30). Thirty-four percent (n=259) reported >50 nights of prior experience in the prior 10 years, and 43% (n=331) logged between 11 and 50 overnights over that time frame. Ten nights or less comprised 19% (n=147). A relationship between prior backpacking experience and morbidity was not evaluated due to the paucity of backpackers lacking experience.

The average pretrip planned rate of travel was 19±6 (5.6–56) $km \cdot day^{-1}$ (11.9±3.7 [3.5–35] $mi \cdot day^{-1}$). The actual reported rate of travel of 19.8±6.3 (5.6–72.4) $km \cdot day^{-1}$ (12.3±3.9 [3.5–45] $mi \cdot day^{-1}$) was similar but statistically higher than the planned rate of travel (P<0.001). In contrast, only 19% (n=135) were unable to complete their daily distance as planned. Increasing age (P<0.001), BPW (P<0.001), and BMI (P<0.001) were all correlated with a decrease in the rate of travel. Hikers completed their trips in 15.2±7.6 (5–35) days and travelled 272±129 (45–1207) km (169±80 [28–750] mi). Rate of travel had no predictive relationship with medical illness, injury, or evacuation.

BPW was 10±3.6 (2.3–23) kg (22.4±8 [5–50] lbs), as seen in Figure 4. No correlations were identified between age and BPW. BPW distribution was "heavy" (>13.6 kg [30 lbs]) for 18% (n=128); "traditional" (<13.6 kg [30 lbs]) comprised 37% (n=267); "lightweight" (<9.1 kg [20 lbs]) was the majority at 41% (n=299); "ultralight" (<4.5 kg [10 lbs]) at 4.5% (n=34); and there was only 1 (0.1%) "super-ultralight" (<2.3 kg [5 lbs]). Increasing BPW (P = 0.032, 95% CI 1.002–1.042) increased the likelihood of illness or injury.

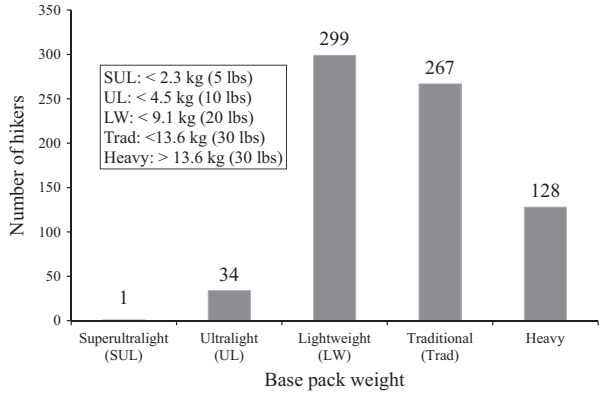

Figure 4. Base pack weights. Base pack weights carried by backpackers are illustrated by category.

MEDICAL ISSUES

Over half (57%) of respondents had some form of medical problem or injury, with blisters (57%) and sleep problems (57%) being the most prevalent (Table 2). Altitude sickness was self-reported in 37% of hikers. Altitude illness in the survey was described as "symptoms of headache, edema, low energy, mental confusion, clumsiness shortly after getting to elevation – do not use this merely because you felt short of breath on climbs." Musculoskeletal complaints were common, including pain related to pack straps (46%), knee and ankle pain (44%), back pain (43%), heel pain (21%), and muscle cramps (21%). Falls or other forms of trauma were not uncommon (16%), and 1.3% reported fractures.

Musculoskeletal complaints generated the most comments regarding morbidity of any category (229 free-text comments), with 14 reporting unplanned early trail exit due to musculoskeletal pain—more than any other category. Hikers attributed pains to bruising from pack weight, sequelae from falls, and exacerbation of pre-existing conditions. The majority of described injuries were minor but persistent in nature, such as sprained ankles, joint pain, abrasions, bruising, and stress fractures of the feet. Serious injuries were uncommon. One hiker described a fall resulting in a torn tendon requiring surgery and another reported a fall with resulting facial fracture. Two falls resulted in injuries requiring assisted evacuation. Heel pain and foot pain were diagnosed by hikers as either plantar fasciitis or blistering conditions. Blisters affected 57%. Blister severity in free-text comments (n=73) ranged from benign, noting resolution with footwear change (from boots to sneakers or sandals, or adding gaiters), to severe. Blisters ended trips in 2 cases; descriptive comments included "socks and sneakers were soaked with blood."

Bowel irregularities were not common among JMT hikers. Diarrhea was present in 17%, mostly rated as minor in severity; 10% endured minor constipation. The

Table 2. Most common illnesses and injuries on the JMT

		Minimal rating	*Significant/Severe rating*
Problem	*% Affected*	*Raw no. of responses (% of those answering)*	*Raw no. of responses (% of those answering)*
Blisters	57	305 (45)	103 (15)
Sleep problems	57	331 (46)	75 (11)
Pack strap pain	46	267 (38)	57 (8)
Knee/Ankle pain	44	223 (32)	89 (13)
Back/Hip pain	43	269 (38)	33 (4.7)
Excessive fatigue	41	254 (36)	39 (6)
Excessive shortness of breath	37	217 (31)	47 (7)
Altitude illness	37	213 (30)	46 (7)
Headache	33	215 (30)	17 (2)
Other chafing/rashes	33	192 (27)	41 (6)
Heel pain/Plantar fasciitis	21	109 (15)	40 (6)
Muscle cramps	21	136 (19)	11 (1.6)
Diarrhea	17	100 (14)	23 (3.2)
Fall/Other trauma	16	80 (11)	33 (4.6)
Constipation	11	74 (10)	7 (1)
Hypothermia	7	38 (5)	12 (1.7)
Skin infection	6	34 (4.8)	7 (1)
Heat illness	5	32 (4.5)	6 (0.8)

JMT, John Muir Trail.

vast majority of hikers (88%) were regularly compliant with water filtration practices.

Conditions requiring medical attention were reported by 8% (n=62). A persistent condition for which medical attention was not sought was even more common; 19% (n=145) reported issues lasting at least 2 weeks after the conclusion of their trip. Infections noted among respondents included cellulitis requiring hospital admission midtrip and several reports of suspected parasitic infections, which included a hiker who was hospitalized for a week. Thirty hikers were forced to leave the trail; 4 required EMS, 3 by helicopter. The helicopter rescues included bilateral foot stress fractures, a traumatic fall (unspecified), and gastrointestinal illness resulting in the inability to tolerate oral intake. The EMS-assisted hike out was for a fall with facial fractures requiring hospitalization. Of all hiker characteristics, only an increasing BMI was associated with higher likelihood of trail evacuation (P=0.003, 95% CI 1.041–1.225) (Table 3).

Discussion

The sample size required to generate a data set that accurately reflects the behavior of JMT hikers was calculated to be 347 respondents.[7] This calculation was based on the population of 3500 total JMT hikers as estimated by Yellowstone National Park for the 2014 season.[8] The 771 respondents of the 2014 JMT survey exceeds this minimum sample size. According to the National Park System website, from 2011 to 2015, there has been a 100% increase in JMT permits requested; there were fewer than 500 JMT hikers in 1998 and over 3500 in 2016.[8] Understanding the experiences of the JMT hiker is of vital importance as the popularity of long-distance backpacking continues to rise.

Table 3. Regression model for hiker demographics and illness/injury and evacuation

		95% CI		
Demographics	*Odds ratio*	*Lower*	*Upper*	P *value*
Medical Illness/Injury				
Age	0.997	0.965	0.988	***0.000***
Sex	1.291	0.921	1.811	0.138
BMI	1.051	1.008	1.096	***0.021***
Conditioned (Y/N)	1.082	0.759	1.541	0.664
Base pack weight	1.022	1.002	1.042	***0.032***
Miles per day	1.000	0.959	1.044	0.988
Evacuation				
Age	0.993	0.963	1.024	0.655
Sex	1.657	0.706	3.892	0.246
BMI	1.129	1.041	1.225	***0.003***
Conditioned (Y/N)	1.288	0.499	3.326	0.601
Base pack weight	0.971	0.924	1.021	0.250
Miles per day	1.072	0.984	1.167	0.112

BMI, body mass index.
Bolded and italicized items represent statistical significance.

The cohort of hikers who responded to the survey were mostly adult respondents who self-assessed as "at or above-average fitness" regardless of prehike exercise activity. Overall, they demonstrated a commitment to prehike conditioning (73% performed hard physical activity for 4 hours per week or more in advance of their trip). Of Long Trail hikers in Vermont, the results were similar, with 81% performing prehike conditioning.[3] Although the authors hypothesized that fitness would be beneficial to decreasing injury and illness, the lack of correlation in the JMT cohort reflects the previously reported absence of a relationship between prehike conditioning and either the type or incidence of musculoskeletal trauma incurred.[2,3] However, the correlation with BMI with both a slight increase in illness and injury, as well as being the only hiker characteristic significantly affecting likelihood of evacuation, suggests the fitness lifestyle of the respondent may be far more influential than the training that occurs only 4 weeks preceding the trip.

The prevalence of illness and injury (57%) is less than prior reports on eastern US trails. Among through-hikers of the AT from 1987 to 1988, morbidity was 82%, mostly attributable to musculoskeletal complaints, trauma, and diarrhea.[2] The higher incidence of diarrhea on the AT (68% in 1988; 56% in 1997) in comparison to the JMT (17%) has been attributed to low coliform counts in backpacker sites on the JMT as well as higher reported compliance rates with water treatment practices on the JMT.[9] Hikers of the Long Trail in Vermont from 1986 had a 68% prevalence of medical issues, largely comprising musculoskeletal complaints.[3] In 1997, AT hiker morbidity was 64%, with blisters and diarrhea predominating and musculoskeletal problems (36%) declining.[10] The slight beneficial correlation between BPW and decreasing prevalence of illness and injury found in the regression model of the JMT cohort suggests that the increasing popularity of lightweight backpacking may be responsible for these downward trends in injury rates in the backpacking community. Nearly half (45%) of the 2014 JMT hikers carried a pack base weight qualifying as lightweight or lighter.

Sleeping difficulties and altitude-related complaints were prevalent on the JMT. These issues have not been queried in other published surveys of long-distance backpackers. Sleep disturbances were attributed to altitude illness and other factors in free-text comments: weather (lightning storms causing distress, low overnight

temperatures), uncomfortable sleeping equipment, muscle soreness, pack-related pain, and safety concerns regarding camping solo. Many hikers noted the resolution of altitude illness, including insomnia, approximately midway through their trip. Only 1 respondent reported being forced to halt or reroute the trip to descend to a lower elevation due to symptom severity related to altitude.

The hypothesis that conditioned lightweight backpackers covering more distance per day would have higher trip completion rates with fewer adverse events was partially supported. Lightweight BPW did decrease morbidity. Higher BMI did increase morbidity. However, conditioning did not decrease morbidity, similar to other studies' findings.[2,3] Perhaps neither BMI nor prehike conditioning can reliably reflect baseline fitness. Furthermore, trip completion was defined as whether evacuation occurred. Given the large sample size, which included both through-hikers and section hikers (hikers who plan on completing only a portion of the JMT), total distance hiked was not used as a marker. It would have been impractical to determine which individuals were through-hikers who did not complete their trip as planned vs section hikers who did complete their trip as planned. Future investigation of hikers who ended their trip unexpectedly would be of value.

LIMITATIONS

Participant recall bias often affects survey responses in an overly positive manner and must be considered. The high proportion of respondents reporting illness or injury in association with their JMT hike mitigates this concern. Selection bias was lessened to the extent possible by the large proportion of trail users as respondents, but an undercoverage bias of those not active in online hiking communities is likely. Solicitation on site was meant to mitigate undercoverage bias but is likely less effective compared with regular users of social networks interacting with sites advertising the survey link. Nonresponse bias could have affected participation by those experiencing significantly negative outcomes.

The use of a survey not designed for the purpose of this study must be addressed. A survey of this scope and high response rate needs not be invalidated for this reason alone. Goals of investigation were defined before any analysis of the data by the authors. The survey instrument is not validated for reliability, validity, or sensitivity, nor were the rating scales used within. Several answer choices used colloquial language, which could be misinterpreted. The survey author performed post hoc verification of outlier values before releasing the data; this practice of verifying outlying data, in this large sample, likely has little impact on the interpretation of the results. Free-text comments may introduce a nonresponse bias; as such, these comments are not used as a primary outcome.

Conclusions

JMT hikers experienced medical issues similar to those reported on other national trails, with the exception of less diarrhea incidence and a drop in musculoskeletal complaints. This drop in musculoskeletal complaints is likely related to overall decreases in BPW among experienced backpacker populations. We conclude that it would be worthwhile for backpackers to invest in lightweight equipment and to make reasonable attempts to maintain their weight and fitness. Pack weight and BMI were the only independent variables to significantly correlate with trip completion and adverse events. Furthermore, although conditioning in the few weeks before the hike did not correlate with trip completion and adverse events, it did relate to hikers' perception of the difficulty of their trip. We also suspect that experience matters because most hikers had at least a moderate amount of backpacking experience and because older hikers had fewer negative outcomes.

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