Effects of using the *Trekker's Friend* hiking trailer to transport a pack: 2020 test

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EXECUTIVE SUMMARY

A lightweight and demountable hiking trailer has been developed by Chris Lowe, the author of this paper. Called the *Trekker's Friend,* it was designed to make multi-day walks with a pack easier and more enjoyable. The *Trekker's Friend* has three unique features which give it a distinct advantage over other hiking trailers which are that it:

- Is lightweight – weighing only approximately 1.6 kg
- Is demountable – allowing walkers to pull their pack along on easier terrain, and then carry their pack with the device attached when the terrain is too rough for the trailer
- Incorporates the walker's trekking poles in its frame when being used as a trailer.

This report presents the findings of testing conducted to determine how using the hiking trailer compares to carrying a pack in terms of energy usage, walking speed, cadence and heart rate. These measures were selected to understand the effects on walking of carrying vs. wheeling a backpack and also as they are good indicators of the amount of effort required for each method of transporting a backpack.

A series of 54 test walks were taken on a 11.6 km circuit between July and October 2020. Six test walks each time were done walking without a pack, carrying a pack, and taking the pack on the trailer, with packs weighing 8 kg, 13 kg, 18 kg and 23 kg.

The study found that:

- The test subject walked from 4.5% to 7.8% faster when using the trailer compared to carrying the backpack. The increase in speed was statistically significant for all load weights and generally increased as the load increased
- The test subject's heart rate varied slightly but did not differ in a statistically significant way for any transport method for any load weight
- The test subject's cadence increased by 2.4% to 5.5% when using the trailer, and the increase in cadence was statistically significant for all load weights and generally increased as the load increased
- The test subject consumed from 1.3% to 14.5% less energy per km when using the trailer. This reduction was statistically significant for load weights above 8 kg, and generally increased as the load increased
- The test subject consumed from 3% more to 9.6% less energy per hour when using the trailer. However, the differences were only statistically significant for load weights above 13 kg when using the trailer required about 9% less energy consumption per hour.

In summary, this study found that transporting a pack on the *Trekker's Friend* hiking trailer on good surfaces allows the user to walk faster than if they carry the backpack. While walking faster, for loads of 8 kg and above, they use less energy per unit distance and, for loads of 18 kg and above, they also use less energy per unit time.

These results contrast with other studies of energy consumption when walking that have found that walking faster uses more energy: this study showed that using a hiking trailer allowed the subject to walk faster while, at the same time, using less energy.

This paper does not claim to represent independent testing: all testing and analysis was done by the inventor of the *Trekker's Friend* trailer which introduces a degree of bias. In addition, the findings in this paper are not commercial claims for the *Trekker's Friend*: anyone purchasing or using the device will need to perform their own testing to establish whether it meets any given standard or fulfills their requirements.

INTRODUCTION

A lightweight and demountable hiking trailer called the *Trekker's Friend* has been developed by Chris Lowe, the author of this paper. It attaches to a backpack allowing the pack to be wheeled much of the time. Over rougher or steeper stretches of the trail where the trailer can't be used, the pack is carried like a regular backpack with the trailer assembly attached.

This report presents the findings of testing conducted to determine how using the hiking trailer compares to carrying a pack in terms of energy usage, walking speed, cadence and heart rate.

BACKGROUND

The inventor of the *Trekker's Friend* has been a trekker and bushwalker for around forty years and has been on many multi-day walks, both in Australia and overseas. However, he found carrying a heavy pack for long distances was uncomfortable, and sometimes even painful.

He noticed that large portions of many walking tracks were wide and smooth enough that a pack could potentially be wheeled along. However, the wheel assembly used for suitcases wasn't designed for taking luggage over longer distances or on bush tracks, and existing hiking trailers are generally heavy and difficult to dismantle so make progress difficult when the walker encounters rough or steep terrain.

The solution was to design a lightweight demountable hiking trailer, which could be used to wheel the backpack when the terrain allowed, and carried on the user's back, attached to the rucksack, when necessary.

A particular challenge in developing the trailer was making it as light as possible whilst still being strong enough to carry a heavy pack over bumps and steps in the track. A unique feature of the *Trekker's Friend's* lightweight design is that the walker's trekking poles form part of its frame when being used as a hiking trailer. These can be detached and used in the normal way for walking when rougher terrain is reached and the pack has to be carried. This approach works well as trekking poles are most useful to assist with walking when the terrain is rough steep or slippery, which is just the sort of terrain that is not suitable for a hiking trailer.

The *Trekker's Friend* weighs approx 1.6 kg and has been designed to carry the typical backpacking loads of 8 to 25 kg.

Since it was specifically designed to reduce the effort of taking a pack on hikes, its inventor has conducted a study of the effects of using the trailer on energy consumption and walking speed compared to carrying the pack. The study also recorded and checked the effects on cadence and heart rate to help to understand why any other effects occurred.

PURPOSE

The purpose of this study was to compare the effects of using the *Trekker's Friend* hiking trailer to transport a pack with the effects of carrying the pack.

Energy consumption was the key measure examined because it corresponds most directly to the amount of effort required. However, there are two aspects to energy consumption: energy consumed per unit time, and energy consumed per unit distance. Each of these was analysed separately.

As effort may also affect how much work the heart has to do in supplying the body with oxygen during exertion, heart rate was measured as well.

The effects on walking speed were examined to see whether the energy saved by using the hiking trailer allowed the subject to walk faster. Cadence was also examined as it is an aspect of walking that might be affected by transporting a load.

In summary, this study looked at the following key questions about the effort required to transport a pack when walking:

1. How is energy consumption affected by carrying a pack vs using a hiking trailer to transport it? How do these effects vary for energy consumption per unit distance or per unit time?
2. How are heart rate and cadence affected by using the hiking trailer for a pack compared to carrying it?
3. What effect does using the hiking trailer to transport a pack have on walking speed?

Several load weights were used to investigate how energy expenditure, walking speed, cadence and heart rate varied as the load weight increased.

METHODOLOGY

Testing involved three steps:

1. Conducting a series of test walks
2. Measuring energy expenditure, walking speed, cadence and heart rate during the course of the walks
3. Analysing the results.

1. Conducting Test Walks

To allow comparisons between using the *Trekker's Friend* trailer and carrying a pack, a series of test walks were conducted for each of the following modes of travel:

- Walking with no load
- Walking while carrying a pack
- Walking while pulling a pack along with the *Trekker's Friend* hiking trailer.

Test walks were conducted around a 11.6 km circuit along a sealed recreation path in Canberra. The course had a total altitude variation of about 110 metres. For details on the location and altitude of the course see Appendix A1.

Four different load weights were tested with both the hiking trailer and carrying the pack: 8 kg, 13 kg, 18 kg and 23 kg.

The minimum pack weight tested was 8 kg as this was thought to be the minimum that most people would consider using a hiking trailer to transport. The maximum weight tested was 23 kg being the upper limit of what most walkers would usually carry.

Six repetitions were done for each mode of travel, and for each of four weights when taking the pack. This means a total of 54 test walks were conducted (6 with no load, 24 carrying the backpack, and 24 pulling the backpack), producing 54 sets of measurements.

Testing was conducted over several months, between July and October 2020 and thereby covered a variety of weather conditions as the weather changed from winter to spring.

The test subject was the inventor of the *Trekker's Friend* and author of this study.

2. Measuring Walking Speed, Heart Rate, Cadence and Energy Expenditure

The main variables that were measured were:

- Energy expenditure – recorded in kilocalories (kcal) which was then converted to kilojoules (kJ)
- Walking Speed – in kilometres per hour (km/h)
- Cadence - in revolutions per minute (rpm)
- Heart rate – in beats per minute (bpm).

These variables were measured with a Suunto Ambit Run GPS watch and heart monitor which was worn by the test subject for each test walk.

To ensure the testing was as comparable and standardised as possible:

- The load weight of the backpack was measured and was the same when it was being carried as when it was on the hiking trailer
- Trekking poles were not carried or used to assist walking either when walking with no load or when carrying the backpack
- The weight of the hiking trailer components and the trekking poles was not included when measuring the weight of the backpack - ie. They were additional to the load when using the hiking trailer. Together, these weighed approximately 2 kg. Therefore, for example, when transporting an 8 kg backpack, the test subject walked without hiking poles and just carried an 8 kg backpack; when transporting an 8 kg backpack on the hiking trailer, the test subject used trekking poles and the hiking trailer assembly to make the hiking trailer and added to that the 8 kg backpack, making a total load of approximately 10 kg
- The circuit was walked no more than once per day, at approximately the same time of day –after breakfast, at some time between 7am and 10am
- The test subject traversed the circuit in the same direction for every test walk
- The order of testing each combination of load/transport method was pseudo-random rather than any repeating pattern
- If the weather was not reasonably fine for an entire test walk, or the walker was sick or injured, no testing was done and any partial results from the test walk were discarded
- The course was walked around 5-10 times, including with a loaded backpack and hiking trailer, before beginning the recorded test walks
- If a test walk needed to be halted, for example to get a drink or adjust clothing, the 'pause' function on the watch was used to exclude this period

- The test subject walked alone.

The test subject did not attempt to walk at any particular speed – they could walk at whatever speed that felt comfortable.

3. Analysing the Results

The results were analysed in the following way:

- At the end of each test walk the test subject entered elapsed time, cadence, walking speed, heart rate and total energy consumption into an Excel spreadsheet. These values were provided by the Suunto GPS watch and Suunto's app
- Decimal hours for elapsed time, energy expenditure per kilometre and energy expenditure per hour were calculated using Excel functionality
- The amount of energy required to transport the pack by carrying it was compared to the amount of energy required to transport it with the hiking trailer – for each weight
- Statistical tests were conducted using the 0.05 significance level to determine whether the differences in readings when using the hiking trailer (compared to carrying the pack) were statistically significant. For details on how the statistical tests for significance were done see Appendix A.2.

Note: If a difference is said to be "statistically significant" it means that it is reasonable to have a given level of confidence that the difference is not simply due to chance. In this paper, "T-tests" were performed using the 0.05 significance level to provide a 95% level of confidence that the differences between the samples was not due to chance.

RESULTS

Walking Speed

Differences in average walking speed according to the mode of travel (over the course of the 11.6 km track) are shown in Figure 1 and indicate that:

- With no load, the average walking speed was 5.32 km/h
- When using the walking trailer, speed of walking only changed very slightly from that, no matter what the load, but it changed much more when carrying the backpack
- The test subject walked more slowly when carrying the pack than when wheeling it, and the difference became greater as the pack's weight increased. The difference between them was significant for all load weights
- The average speed when pulling the pack was slightly faster (by less than 2%) than when walking without a load - for 8 kg and 13 kg.

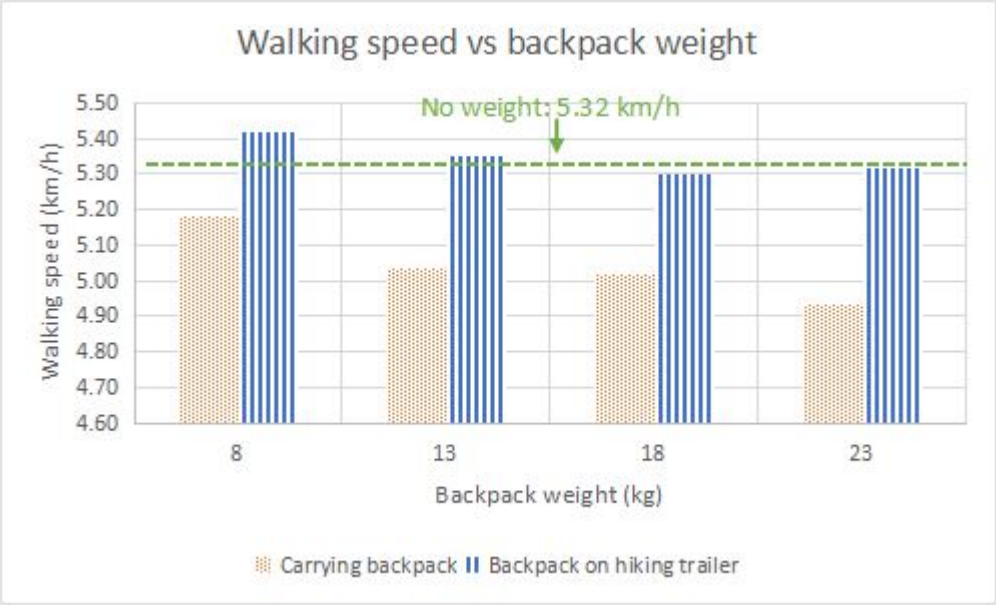

Figure 1: Walking speed

Table 1 below shows the relative increase in walking speed when using the hiking trailer compared to carrying the pack. These results indicated that:

- The differences in walking speed according to whether the pack was carried or pulled on the trailer were statistically significant, for all load weights
- The improvement in walking speed when using the hiking trailer (compared to carrying the pack) became greater as the load increased - from 4.5% with 8 kg to 7.8% with 23 kg.

Speed (km/h) vs backpack weight	No load:	5.32	km/h	
Load (kg)	8	13	18	23
Backpack on hiking trailer	5.42	5.35	5.30	5.32
Carrying backpack	5.18	5.03	5.02	4.93
Effect of putting backpack on hiking trailer (change in km/h)	0.2	0.3	0.3	0.4
Effect of putting backpack on hiking trailer (% of value for carrying)	4.5%	6.3%	5.6%	7.8%
Significant or not	YES	YES	YES	YES

Table 1: Walking speed

Heart Rate

As shown in Figure 3 below, the test subject's average heart rate:

- Was 88.7 bpm when walking with no load
- Increased slightly when walking with packs of all weights, compared to walking without one
- For lower pack weights the heart rate was higher when the pack was on the hiking trailer, but this was reversed for higher pack weights
- Heart rates did not greatly differ between modes of transport as the weight varied.

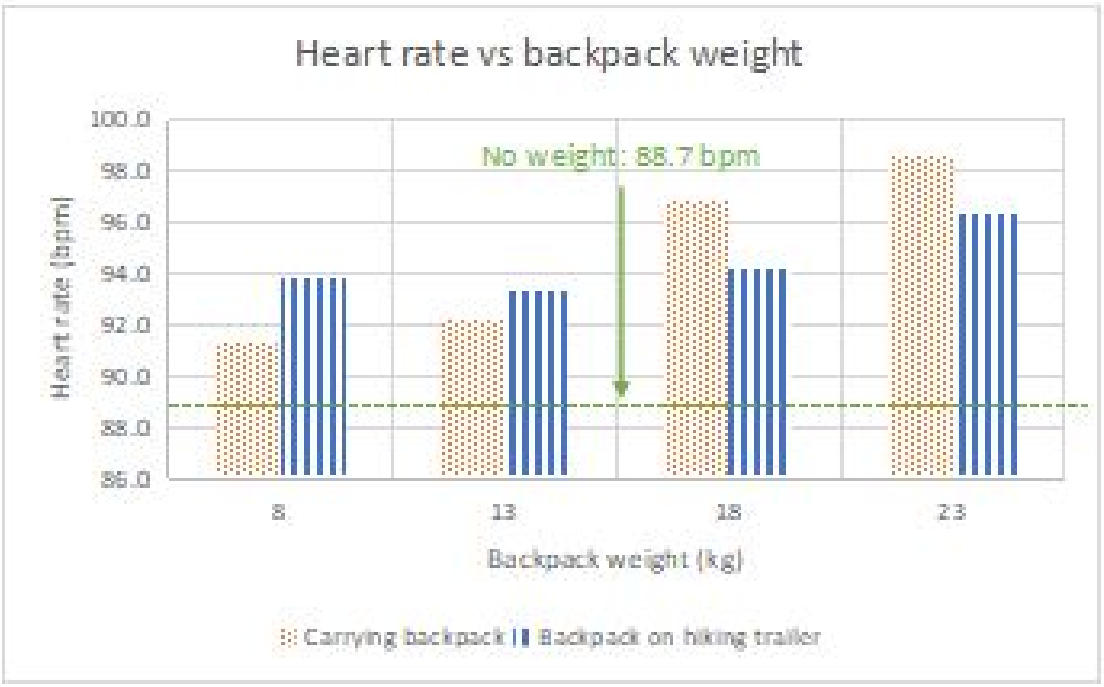

Figure 2: Heart rate

Table 3 below shows the relative change in heart rate when using the hiking trailer compared to carrying the pack. These results indicated that:

- The differences in heart rate according to whether the pack was carried or pulled on the trailer were very small and not statistically significant, for any load weight.

Heart rate (bpm) vs backpack weight	No load:	88.7 bpm		
Load (kg)	8	13	18	23
Backpack on hiking trailer	93.8	93.3	94.2	96.3
Carrying backpack	91.3	92.2	96.8	98.7
Effect of putting backpack on hiking trailer (change in bpm)	2.5	1.2	-2.7	-2.3
Effect of putting backpack on hiking trailer (% of value for carrying)	2.7%	1.3%	-2.8%	-2.4%
Significant or not	NO	NO	NO	NO

Table 2: Heart rate

Cadence

As shown in Figure 3 below, the test subject's cadence:

- Was 49.2 steps per minute when walking with no load
- Was slightly higher when carrying with an 8 kg pack but decreased slightly when walking with packs of 13 kg and above
- Was always higher when the pack was on the hiking trailer.

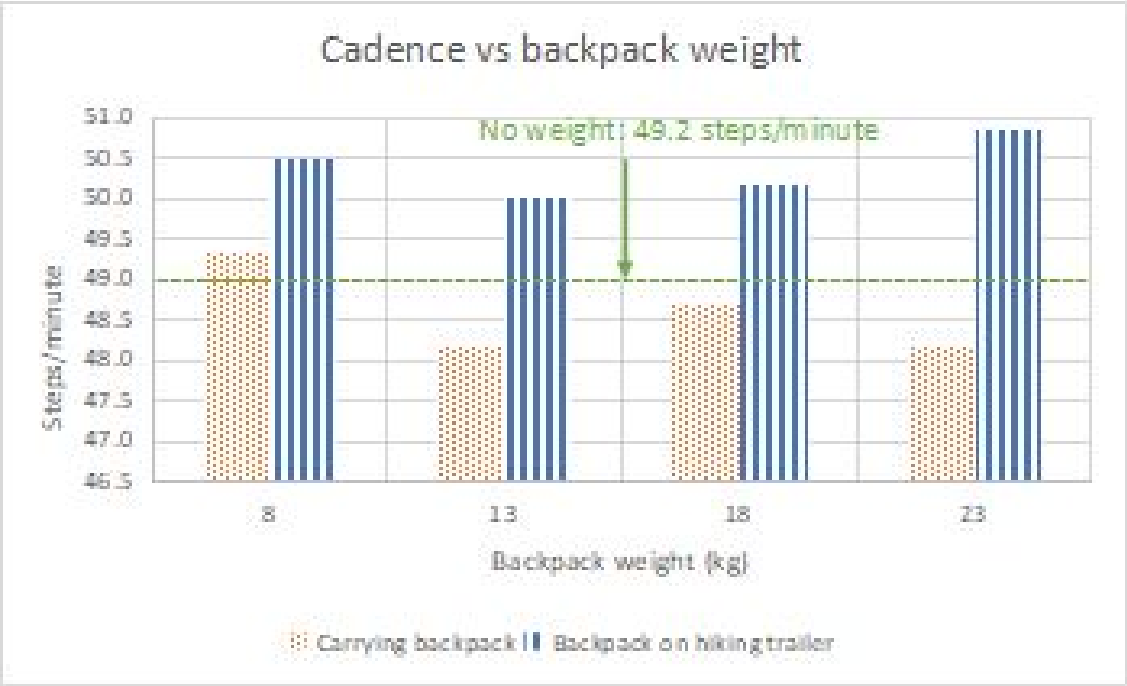

Figure 3: Cadence

Table 3 below shows the relative change in cadence when using the hiking trailer compared to carrying the pack. These results indicated that:

- The differences in cadence according to whether the pack was carried or pulled on the trailer, though small, were always statistically significant, for every load weight. There was a general trend of gradually increasing differences as the load weight became heavier

Cadence (steps/minute) vs backpack weight	No load:	49.2 steps/minute		
Load (kg)	8	13	18	23
Backpack on hiking trailer	50.5	50.0	50.2	50.8
Carrying backpack	49.3	48.2	48.7	48.2
Effect of putting backpack on hiking trailer (amount)	1.2	1.8	1.5	2.7
Effect of putting backpack on hiking trailer (% of value for carrying)	2.4%	3.8%	3.1%	5.5%
Significant or not	YES	YES	YES	YES

Table 3: Cadence

Energy Consumption Per Kilometre

The energy consumption per kilometre was calculated by dividing the total energy consumption for the circuit by the number of kilometers in the test circuit. As shown in Figure 4 below, the test subject's energy consumption per unit distance:

- Was 242.3 kJ per km when walking with no load
- Gradually increased as the pack weight increased, when the test subject was carrying the pack
- Increased, but at a lower rate when the pack was on the hiking trailer. Energy consumption per km was almost the same for pack weights of 8-18 kg but was slightly more with a 23 kg pack.

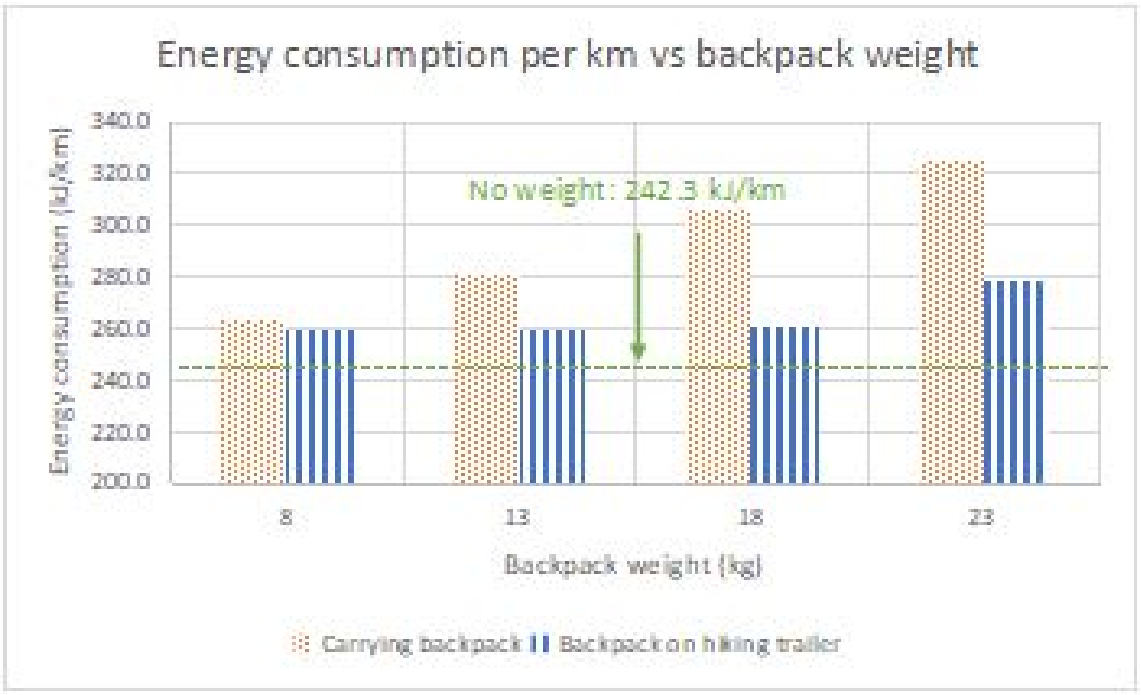

Figure 4: Energy consumption per kilometre

Table 4 below demonstrates how much of the total energy consumed per km when carrying the pack was saved when pulling the pack with the *Trekker's Friend* trailer. The results showed that:

- The relative energy savings per kilometre from using the trailer increased as the load weight increased, from 1.3% with 8 kg to 14.8% with 18 kg and 14.5% with 23 kg
- The difference in total energy consumption per kilometre between carrying the pack and pulling it on the trailer was statistically significant for every weight except 8 kg.

Energy consumption per km (kJ/km) vs backpack weight	No load:	242.3	kJ/km	
Load (kg)	8	13	18	23
Backpack on hiking trailer	259.8	259.1	261.2	277.8
Carrying backpack	263.1	280.6	306.6	325.1
Effect of putting backpack on hiking trailer (change in kJ/km)	-3.4	-21.5	-45.4	-47.3
Effect of putting backpack on hiking trailer (% of value for carrying)	-1.3%	-7.7%	-14.8%	-14.5%
Significant or not	NO	YES	YES	YES

Table 4: Energy consumption per kilometre

Energy Consumption Per Hour

The energy consumption per hour was calculated by dividing the total energy consumption for the circuit by the decimal number of hours taken to walk the test circuit. As shown in Figure 5 below, the test subject's energy consumption per unit time:

- Was 1,286 kJ per hour when walking with no load
- Gradually increased as the pack weight increased, when the test subject was carrying the pack
- Increased, but at a lower rate when the pack was on the hiking trailer. Energy consumption per hour was almost the same for pack weights of 8-18 kg but was slightly more with a 23 kg pack.

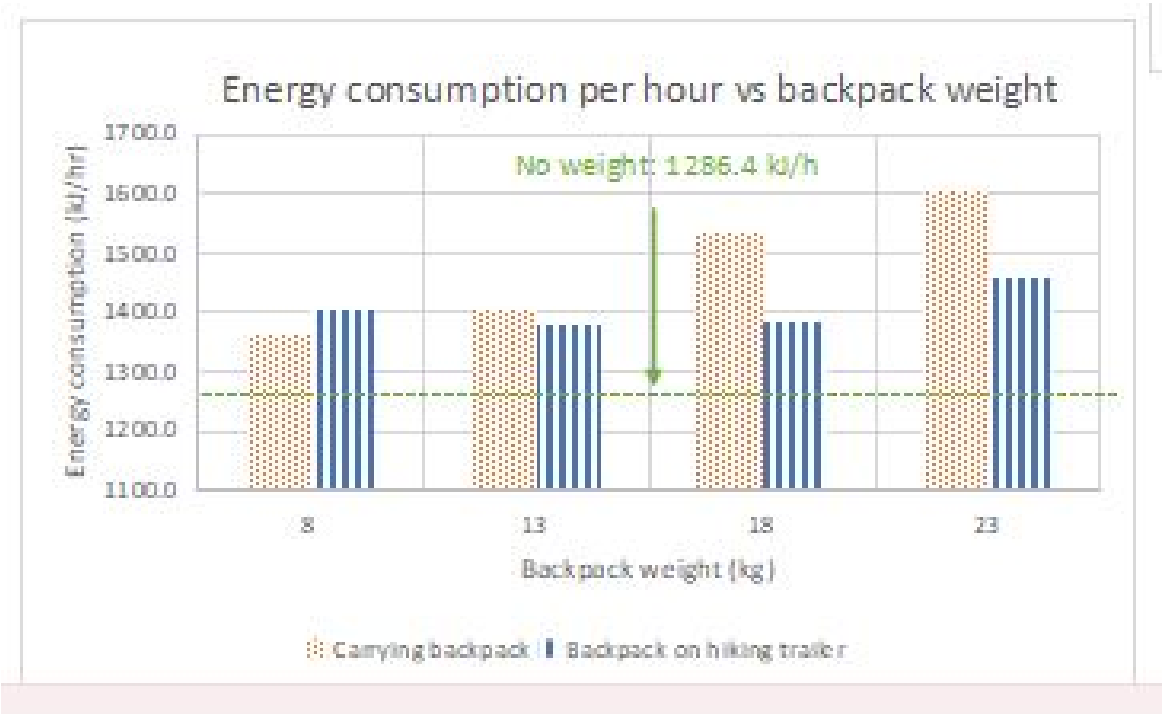

Figure 5: Energy consumption per hour

Table 5 below demonstrates how the energy consumption per hour changed when pulling the pack on the *Trekker's Friend* trailer vs. carrying the pack. The results showed that:

- The energy consumption per hour did not significantly differ between using the trailer and carrying the pack with load weights of 8 and 13 kg
- It was reduced by 9% per hour for higher weights, and this was statistically significant.

Energy consumption per hour (kJ/h) vs backpack weight	No load:	1286.4 kJ/h		
Load (kg)	8	13	18	23
Backpack on hiking trailer	1402.6	1379.3	1386.5	1458.7
Carrying backpack	1361.4	1402.8	1533.7	1603.0
Effect of putting backpack on hiking trailer (change in kJ/h)	41.3	-23.5	-147.2	-144.3
Effect of putting backpack on hiking trailer (% of value for carrying)	3.0%	-1.7%	-9.6%	-9.0%
Significant or not	NO	NO	YES	YES

Table 5: Energy consumption per hour

Summary of Results

This study found that:

- The test subject walked from 4.5% to 7.8% faster when using the trailer compared to carrying the backpack. The increase in speed was statistically significant for all load weights and generally increased as the load increased
- The test subject's heart rate varied slightly but did not differ in a statistically significant way for any transport method for any load weight
- The test subject's cadence increased by 2.4% to 5.5% when using the trailer, and the increase in cadence was statistically significant for all load weights and generally increased as the load increased
- The test subject consumed from 1.3% to 14.5% less energy per km when using the trailer. This reduction was statistically significant for load weights above 8 kg, and generally increased as the load increased
- The test subject consumed from 3% more to 9.6% less energy per hour when using the trailer. However, the difference was only statistically significant for load weights above 13 kg when using the trailer required about 9% less energy consumption per hour.

The comparisons between carrying a pack and using the *Trekker's Friend* hiking trailer are summarised in Table 6 below. Statistically significant findings are **bolded**, and those that were not statistically significant are in *italics*. The summarised findings are as follows:

Summary table				
Load (kg)	**8**	**13**	**18**	**23**
Change in walking speed with trailer	**4.5%**	**6.3%**	**5.6%**	**7.8%**
Change in heart rate with trailer	*2.7%*	*1.3%*	*-2.8%*	*-2.4%*
Change in cadence with trailer	**2.4%**	**3.8%**	**3.1%**	**5.5%**
Change in energy consumption per km with trailer	*-1.3%*	**-7.7%**	**-14.8%**	**-14.5%**
Change in energy consumption per hour with trailer	*3.0%*	*-1.7%*	**-9.6%**	**-9.0%**

Table 6: Summary of results

DISCUSSION

Key Findings

The main purpose of this study was to investigate how the effort required to take a pack when walking was affected by using the *Trekker's Friend* hiking trailer to wheel the pack instead of carrying it on the walker's back. It was expected that wheeling the pack on a trailer would use less energy per km than carrying it, and this was what the study showed. However, it is remarkable that the hiking trailer allowed the test subject to use less energy per km while walking faster. Both of these effects were recorded for all load weights, and were always statistically significant except for the energy consumption per km with an 8 kg weight, which showed the same effect but this was not statistically significant. These effects were also observed in an earlier study performed by the author (Lowe C & Lowe I, 2019).

A secondary purpose was to measure how other aspects of walking were affected by using these two methods to carry the pack. The test subject's cadence was always faster when using the trailer than when carrying the pack, though further study is required to understand the significance of this measure.

The study found that the test subject's heart rate did not differ significantly between the two modes of transport for any pack weight: heart rate increased gradually for both modes of transport as the pack weight increased. The study found that that differences in the energy use per hour did not follow any clear trend for low pack weights though it was significantly reduced by using the trailer to carry pack weights of 18 kg and above. Together, these findings suggest that the test subject adjusted their speed of walking to maintain about the same rate of energy consumption per hour as far as possible, which is why their heart rate remained about the same for each method of transport. Using the hiking trailer was an easier way to transport the load over any given distance, which is why, overall, they walked faster and used less energy per km while doing so.

Other research

Several researchers have developed equations to predict energy expenditure while walking (Ludlow and Weyand, 2016). While these equations vary, they all show a direct relationship between walking speed and energy expenditure. Hutchison (2018) notes that the equation developed by Pandolf "has been used since the 1970s to estimate how much energy it takes to hump a pack". This equation predicts that:

1. As the weight of the pack increases, energy consumption per km also increases
2. As the speed of walking increases (above a slow walk of 3.2 km/h) the energy consumption per km increases.

The Pandolf equation, from Hutchison (2018) is as follows:

$$M = 1.5\ W + 2.0\ (W + L)(L/W)^2 + n(W + L)(1.5V^2 + 0.35VG)$$

As Hutchison (2018) stated, in regard to the above:

> "Here M is the metabolic rate, which is how quickly you're burning energy. This equation gives you a value in watts, but that's easy to convert to other units like calories per hour.
>
> The inputs into the equation are:
> - W: your weight (kg)
> - L: the weight of your pack (kg)
> - V: your hiking speed (m/s)
> - G: the grade of any incline (%)
> - n: a 'terrain factor' that adjusts the results for different surfaces (for example, a paved road has a terrain factor of 1.0, but a gravel road is 1.2, since it takes more calories to walk on a soft or uneven surface)."

This analysis will now use this equation to check the energy consumption it predicted against that which was observed in this test. This was done for a single set of tests - that which compared the results for carrying a 23 kg pack or transporting it on the hiking trailer.

When using Pandolf's equation to do this check:

- Speed of walking was recorded in this test as km/hr but Pandolf's equation uses m/s. Speed in km/hr was converted to m/s for this equation by multiplying by 1,000 to give m/hr then dividing by 3,600 to give m/s
- Pandolf's equation gives the answer in watts, or J/sec. This was converted to kJ/hr by multiplying by 3,600 to give J/hr then dividing by 1,000 to give kJ/hr
- Given the speed of walking, mJ/hr was converted to mJ/km by dividing the value for mJ/hr by speed of walking in km/hr.

In testing performed in the current study, the test subject weighed 100kg, and with the 23 kg pack he walked at 4.93 km/h (Table 1). Some of the surfaces on the test circuit are sealed, while others are compacted dirt, so a terrain factor of 1.0 was used. While the test circuit has some short steeper parts overall it is gradually undulating, so G was set to 0. Applying these values to Pandolf's equation

The inputs into the equation are:

- W: 100 (kg)
- L: 23 (kg)
- V: 1.37 (m/s) (ie. 4.93 km/h * 1,000 / 3,600)
- G: 0 (%) (ie. no slope)
- n: 1 (ie. hard surfaces).

The calculated values compared to the average measured values when performing the test walks carrying a 23 kg pack are as follows:

Values for carrying a 23 kg pack, walking at 4.93 km/h		
	Value calculated by Pandolf's equation	**Average measured value**
kJ/h	1,834 kJ/h	1,603 kJ/h (Table 5)
kJ/km	372 kJ/km	325 kJ/km (Table 4)

Table 7: Calculated vs observed energy consumption, carrying a 23 kg pack, walking at 4.93 km/h

When the test subject used the *Trekkers Friend* to pull a 23 kg pack instead of carrying it, the walking speed increased to 5.32 km/h (Table 1). This would mean that when calculating energy usage using Pandolf's equation, V would be set to 1.48.

The calculated values compared to the average measured values when performing the test walks towing a 23 kg pack on the hiking trailer are as follows:

Values for wheeling a 23 kg pack, walking at 5.32 km/h		
	Value calculated by Pandolf's equation	**Average measured value**
kJ/h	2,039 kJ/h	1458.7 kJ/h (Table 5)
kJ/km	383.3 kJ/km	277.8 kJ/km (Table 4)

Table 8: Calculated vs observed energy consumption, wheeling a 23 kg pack, walking at 5.32 km/h

The calculated values compared to the average measured values when performing the test walks towing a 23 kg pack on the hiking trailer are as follows:

Changes between carrying vs wheeling a 23 kg pack		
	Changes calculated by Pandolf's equation	**Change observed**
kJ/h	+11.2%	-9.0%
kJ/km	+3%	-15%

Table 9: Change between walking at 4.93 km/h while carrying pack and walking at 5.32 km/h wheeling pack

In summary, Pandolf's equation predicts that, when a hiker carrying a pack walks at 5.32 km/h vs 4.93 km/h, with a 23 kg pack they will use 11.2% more energy per hour and 3% more energy per km. The tests reported in this paper show that, if they put the backpack on a hiking trailer, they will walk faster while, at the same time, using 9% less energy per hour and 15% less energy per km. This effect is most extreme with heavier pack weights but also seen with lighter packs – ie. walking speed increased although energy consumption per km decreased (see Table 4).

As for the previous subsection, the most likely explanation for this is that since it is easier to pull the pack than to carry it, the subject is able to walk faster while expending less energy per km. This suggests that if the walker had slowed down and walked at the same speed when using the trailer as when carrying the pack, then the savings in energy consumption per km may have been even greater, though this needs to be checked by another study.

Implications of Findings for Using the *Trekker's Friend* in the Field

The *Trekker's Friend* hiking trailer was designed to be used on a wide variety of walking trails and would be particularly useful on multi-day walks where more gear needs to be taken. For overnight trips trekkers would typically cover 15-25 km in a day, and the gradient and elevations could vary considerably over the course of a given route. The terrain and surfaces covered may mean that a hiking trailer may not be able to be used for the entirety of a trip.

This study was conducted in controlled conditions on a fairly level track over the course of 11.6 km. It compared using the *Trekker's Friend* for the entire time with carrying a pack for the entire time. This raises the question of how much one could expect the same advantage in energy consumption described in this study when using the hiking trailer in the field.

First, longer distances would not be expected to make much difference on the proportion of energy that could be saved by using the trailer. This study found that energy was consumed at a constant rate throughout the course of the walk, and therefore the relative energy savings was also constant.

Second, while the trailer will often be used on hilly unsealed surfaces, it becomes more difficult to use as the terrain becomes steeper and/or the surface becomes rougher. User experience indicates (and other testing confirms) that as the track becomes more difficult there is a point, which probably varies with the weight of the pack and the strength of the user, when it takes more effort to use the hiking trailer than to carry the pack.

The *Trekker's Friend* has been designed to cater for these situations by being lightweight and portable so that it can be carried, strapped onto the rucksack, when traversing such terrain. Nonetheless, the *Trekker's Friend* weighs approx. 1.6 kg and when carried with the rucksack this weight will tend to increase the effort required by the user over that used to just carry the pack.

In addition, it takes time and energy to change between carrying the backpack with the *Trekker's Friend* attached and using it as a hiking trailer, and vice-versa. While this is minimal, one would want to change over as infrequently as possible.

Therefore, users would get the most benefit from the *Trekker's Friend* hiking trailer if they:

- Take it on trails that allow it to be used as a hiking trailer for significant portions of the time
- Plan their walk to minimise the number of changeovers required from pulling the pack on the trailer to carrying the pack with trailer attached (i.e. not swapping over for just a short distance)
- Use the Trekker's Friend when carrying a heavier load – as the benefits of using the trailer were greater with heavier packs.

Limitations of the Study

The five main limitations of this study are that:

1. There was only one test subject – a male in his fifties of above average size and average fitness – so results can't be generalised to all potential users of the trailer
2. This single subject was the developer of the *Trekker's Friend*, who also designed, conducted and wrote the study, and therefore it is not an independent study
3. Test walks were performed on reasonably good tracks with little variation in elevation, so results cannot be generalised to all kinds of tracks
4. Testing compared using the trailer exclusively with carrying the pack exclusively, and therefore did not take into account the time or energy required to switch between the two, which would usually occur when using the hiking trailer in the field as it is convertible.
5. It didn't examine the subjective aspects of using the trailer – for example that it is more comfortable to pull a pack on the trailer than carrying it on your shoulders.

The walking course involved a mix of roads, sealed footpaths, good dirt tracks and small tracks. The results presented here would not be the same on other walking routes.

Recommendations for Further Testing

The testing presented here was intended as a pilot study to give a basic indication of how using the *Trekker's Friend* to transport a pack would save effort, primarily in terms of energy consumption. While every attempt was made to perform testing in a rigorous and objective manner, this study has a number of limitations as outlined above.

To address these limitations and both build on and corroborate existing findings it is recommended that further testing be conducted, and that it be conducted:

- By independent researchers
- With multiple test subjects including both males and females and a variety of body sizes and degrees of fitness
- On a wider range of track slopes and surfaces, and
- Incorporating methods for capturing more qualitative data on how using the hiking trailer reduces effort and discomfort compared to carrying a pack.

CONCLUSION

The developer of the *Trekker's Friend* hiking trailer conducted a study of the effects of using the trailer on energy consumption, walking speed, cadence and heart rate, compared to carrying the pack. Test walks were done along a 11.6 km undulating circuit with reasonably good surfaces and with four different pack weights, and also no load at all.

This study found that, when using the hiking trailer to transport a backpack rather than carrying it, the test subject used less energy per hour and per km while walking faster. The test subject's heart rate did not differ significantly when using the trailer or carrying the backpack. Their cadence increased when using the hiking trailer though the implications of this are not clear.

This study was conducted by the developer of the *Trekker's Friend* trailer, who was also the sole test subject. Walks were conducted on a firm path through undulating terrain. This means that results cannot be generalised to a range of walkers and track conditions. Therefore, further independent testing is recommended on different grades of track and with a variety of test subjects.

The results found in this albeit limited study nevertheless indicate that transporting a pack on the *Trekker's Friend* hiking trailer uses substantially less energy than carrying it, and also allows walkers to travel faster at the same time. Further testing will likely find that only the degree of advantage provided by using the trailer may vary from the results presented here, depending on the type of track or varying user characteristics.

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APPENDICES

A.1 The Walking Circuit

The walking circuit used for all test walks, as provided by Suunto is shown in Figure 6 below.

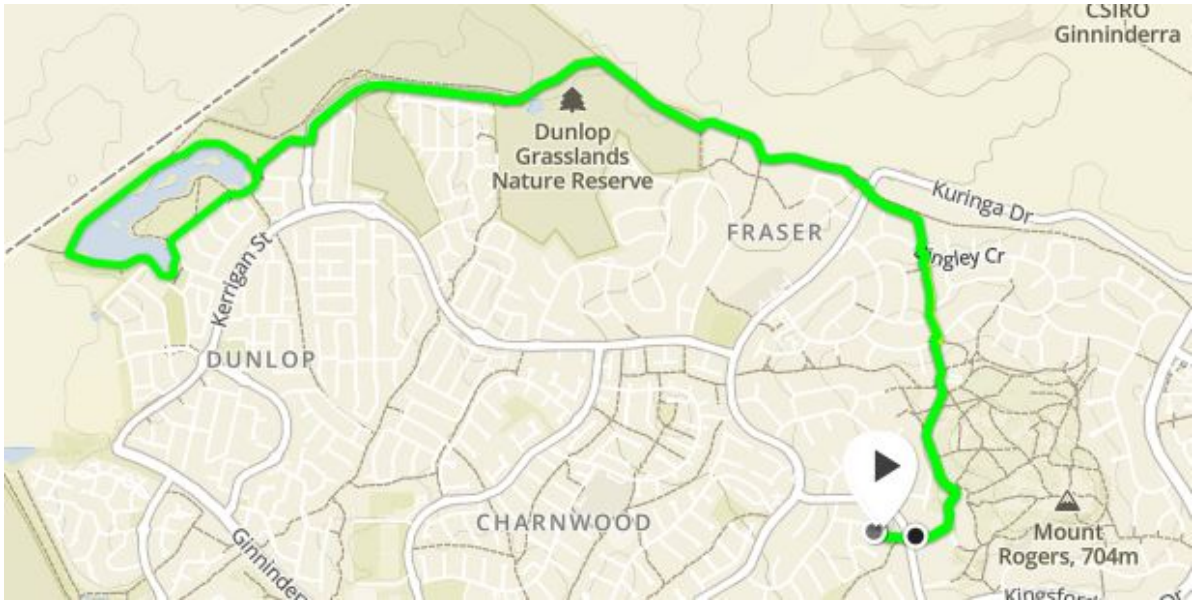

Figure 6: Map of the course

Figure 7: Altitude profile of the course

The Suunto app that supports the use of the Suunto GPS watch worn by the test subject during walks also provides information about the altitude of the course. The course has an average altitude of 603 m and varied from 560 to 674 meters over the course of 11.6 km.

A.2 Determining Statistical Significance

T-tests were used to determine whether two series of test results significantly differed from each other in this paper. A Microsoft Excel function was used to do this: this appendix provides information on how it was done.

When performing a T-test, two values are important:

- The P-value is probably most important and should be less than the level of confidence one is seeking. 0.05 was used in this testing, representing a level of 95% confidence
- The T-value is also important. This is compared against a grid of results that varies depending on the sample size.

Microsoft Excel provides a simple T-test function (t.test()), but this function only returns the P-value, as explained in https://www.rwu.edu/sites/default/files/downloads/fcas/mns/running_a_t-test_in_excel.pdf.

Therefore, the testing reported on in this paper used, instead, a different Excel function that is more complete. It is found under Data ->Data Analysis Tools, named 't-Test: Two-Sample Assuming Equal Variances', and it provides both the P-value and the T-value. An example of the results of using this function are shown in cells M1:O15 in the test results spreadsheet, and the calculation of significance is done in cell)16.

Two sets of data were judged to significantly differ from each other if the P-value was < 0.05 and the absolute value for the T-value was greater than or equal to the number allowed for it, which was provided by the Excel function.

In regard to using this function:

- A paired T-test was not used because there is no pairing between the samples. All tests were performed by one person (the author), on different days, either using the device, walking or carrying in the rucksack. Pairing would only apply if, for example, two people performed each test once separately (ie. once walking, once with the device, once with the rucksack) – the tests performed by each individual person would be paired with the other tests performed by that person
- As noted at https://www.quora.com/How-can-one-interpret-a-negative-t-value-in-a-student-test-p-value-is-very-low, when doing a two-sided T-test the absolute value of the T-value is used. The two-sided T-test was used in this paper
- According to https://www.quora.com/How-can-one-determine-statistical-significance-using-T-Test-in-Excel, the absolute value of the T-value must be greater than or equal to the value provided in a table, which is also provided by the Excel function.

There is no method for calculating the number of iterations of tests that should be performed when using the T-test. Sample size is, however, one of the inputs into the algorithm and will influence the assessment of significance that the T-test provides.